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Harry Loats, Jr., Thomas Fowler,
and Peter Castruccio

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Applications of Remote Sensing to Hydrologic Planning

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and Peter Castruccio
ECOsystems International, Inc.
Gambrills, Maryland

Prepared for
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National Aeronautics
and Space Administration

Scientific and Technical
Information Office

1978

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I. INTRODUCTION

The development of the LANDSAT earth resources satellite has resulted in the availability of new information which has immediate application and utility to environmental planners and managers. However, in order for this new information to be absorbed into common pratice, efforts must be made to *transfer* it from the research sector to the user sector.

Two important steps are required for this transfer process to occur.

1) The applicability and accuracy of individual remote sensing techniques must be confirmed in the user arena.

2) The economic practicality of remote sensing in augmenting or supplanting conventional data sources must be clearly demonstrated.

ECOsystems, under contract to the NASA Marshall Space Flight Center, has focused upon such technology transfer in the area of hydrology and water quality. The ECHOS hydrologic model and the hydrologically oriented remote sensing analysis procedures developed for NAS8-30539 have formed the basis of the transfer task.

Specifically, the work included four tasks:

Task 1. Demonstrate the hydrologic model developed under the previous phase of this work and its corresponding use of LANDSAT imagery to selected users. Explore with the users the active transfer of remote sensing.

Task 2. Perform demonstrations of the value of the hydrologic model and/or of extracting ground cover information from LANDSAT data as may be requested by the more important users.

Task 3. Publish the material, or present it at selected symposia, and similar meetings as indicated by the users.

Task 4. Document user reactions, specific comments, and positive actions taken. Assess and document the nature and magnitude of potential impediments to technological transfer. Generate a case history of user transfer experience and guidelines as an aid in similar efforts by NASA.

True technology transfer is most beneficially accomplished when the transfer encompasses the overall problem as contrasted to problem support areas. The users are mainly interested in the overall results that accrue from the use of remote sensing and secondarily in the specifics of remote sensing, per se. However, once the utility of the remote sensing application is proven, the diffusion of the remote sensing techniques within the user's organization rapidly occurs. Consequently, this project sought to address end-to-end solutions of important problems where remote sensing would play a key role.

The major project chosen for the technology transfer demonstration was the estimation of non-point source water pollutant loading from storm runoff. The need for such data is national in scope and of immediate importance as a consequence of the federal "208" water quality program, which is described in Section III. LANDSAT derived land cover assessments and the hydrologic parameters therefrom is the key input to non-point source load analysis.

Although "208" is a national program, a local focus exists in the Baltimore Regional Planning Council (RPC). This body is charged with preparation of the water quality plan for the 6,123 square kilometer, six county, central Maryland region surrounding Baltimore. Demonstration of the transfer of LANDSAT analysis techniques and the LANDSAT data oriented ECHOS model at the RPC has both local value and national applicability.

The objective of the project was to determine hydrologic response and consequent pollutant loads from important watersheds using remotely sensed land cover. In joint consultation with the RPC, ECOsystems was asked to apply LANDSAT techniques to the estimation of yearly pollutant loads for one of its three designated prototypical test areas, the Magothy Basin in Anne Arundel County, Maryland.

The progress made during the past year has utilized the research and development previously performed for NAS8-30539. The pertinent results of that contract are presented in the following section.

II. SUMMARY OF PREVIOUS WORK

From February, 1974 through February, 1977, ECOsystems has been performing research directed toward the development and validation of a LANDSAT data oriented hydrologic computer model under MSFC contract NAS8-35039. The effort included the following investigations:

1) Identification of those hydrologic phenomena (infiltration, antecedent soil moisture, etc.) which "drive" peak runoff events, i.e., those parameters to which the watershed's outflow is most sensitive.
2) The incorporation of these factors into a hydrologic computer model compatible to the maximum degree with inputs from remote sensing.
3) The verification of the model for actual watersheds.
4) The documentation of procedures for extracting hydrologic information from LANDSAT imagery.

The ability to estimate streamflow from rainfall events is one of the primary requirements of water resources planners and engineers. It impacts the design and construction of waterworks and the plans for future uses for proximate land areas.

The most useful tool available to water resources managers is the computer model designed to simulate the response of a watershed to a given rainfall input. For acceptable performance, these models require specific physiographic and hydrologic data about the watershed. Typical among model parameters are flow lengths, slope, surface friction, soil moisture, and channel characteristics. Current data is either unavailable or expensive to obtain for many basins; therefore, it is advantageous to exploit the low cost and multi-temporal features of satellite remote sensing to provide more complete information as well as periodic updates. Many of the parameters required are surface or surface-inferred phenomena and, therefore, are potentially measurable from earth resources satellites.

The result of contract NAS8-30539 was a hydrologic computer model oriented to the use of LANDSAT data. The model has been tested on well-instrumented watersheds with good results. A set of procedures was also derived for the extraction of necessary input data from LANDSAT images. These procedures involved the analysis of LANDSAT multispectral and multi-temporal images by means of an optical image analysis. The techniques were applied to land cover classification of typical Maryland watersheds. Average inventory errors were typically five percent or less for the important classes. These accuracies were completely satisfactory for derivation of hydrologic parameters such as Manning's "n" and sub-surface abstractions. The computer model and the analytic techniques employed were described in detail in the final report (CR150235; 150236).

While the utility of the techniques and procedures of rainfall to runoff estimates were of definite interest to the important research users, it was obvious that a more practical technology transfer of remote sensing requires the extension of the techniques to the user community. Examples of these user applications are: simulation of flow peak in a flood prediction application, or the use of the rainfall/runoff to estimate pollutant loads. An important result from this analysis was the realization that LANDSAT data could have an important role in the nationwide EPA sponsored "208" program, discussed in the following section.

III. TECHNOLOGY TRANSFER TO THE BALTIMORE REGIONAL PLANNING COUNCIL

The U.S. Environmental Protection Agency, under Public Law 92-500, Section 208, has adopted regulations mandating regional jurisdictions to develop areawide waste water management plans. The purpose of these programs is to ensure that the areas meet the projected 1983 and future water quality regulations. The plans will be used to guide water quality programs through the year 2000. National federal expenditures for "208" programs are presently set at $380 million over a two year time frame. Legislation is currently pending to project future funding requirements.

Until recently, the major thrust of the EPA has been on point sources, i.e., those pollution sources which are confined to spatially limited areas. The "208" program has expanded the scope to include the non-point sources. In contrast to point sources, non-point sources result primarily from the impact of the hydrologic cycle with the land cover. Land cover and associated environmental conditions determine the type, form, concentration and temporal pattern of pollutants for each watershed.

Quantification of non-point pollutant load requires: 1) current and frequent assessment of land cover over large geographic areas; 2) the determination of the relationships between diverse land cover classes and the pollutants they produce; and 3) the determination of the impact of the hydrologic cycle upon the surface and groundwater transport of pollutants. The rapid classification of stable and transient land cover, therefore, is a necessary and valuable adjunct to the "208" program.

Approximately 9-10% of total federal "208" expenditures can be directly or indirectly related to land cover measurements and land cover/non-point source pollutant load correlation. Regional environmental planners with "208" responsibilities, therefore, are an important potential user class interested in LANDSAT derived hydrologic land cover and pollutant load data. *In many cases, only the LANDSAT type data has the sufficiently good resolution and freshness necessary to accommodate the required loading estimates.*

Because of this potential, it was determined to undertake technology transfer with a Section "208" water resources planning body. In the metropolitan Baltimore area, the "208" program is managed by the Baltimore Regional Planning Council (RPC). The RPC is a multi-jurisdictional organization serving a section of the state of Maryland comprised of the City of Baltimore, and the Maryland counties of Anne Arundel, Baltimore, Carroll, Harford, and Howard. The combined area of the region is approximately 6123 km^2 and is composed of 5841 km^2 of land surface and 282 km^2 of surface water. The total area is equivalent to about one-fifth of a LANDSAT frame. Figure 1 shows the member jurisdictions and their proximity to the major population centers of Baltimore and Washington.

The RPC is currently completing a two year, $2.5 million contract from the EPA. The object of this program is to develop pollution abatement plans. The effort is designed to provide the basis for a continuing planning process within this multi-jurisdictional framework.

The RPC has an in-house staff of some 16 professionals supported by 39 specially hired individuals in the separate city and county jurisdictions. The effort is advised on two levels: by project officers (6) from the jurisdictional public works or health offices and by the political heads (6) of the counties, assisted by the presidents of the county councils (6). Figure 2 indicates the staff and advisory personnel and their affiliation to the RPC-208 project. The total project complement is 118, 60 of which are directly working on the project; the remaining 58 are public, local and federal governmental advisors. *This is an important user audience for LANDSAT generated data products.*

Areawide Waste Treatment Management Planning under Public Law 92-500 for the Baltimore area officially got underway in April, 1976. The Regional Planning Council, as the designated agency, was charged with the responsibility of preparing this areawide plan and for administering the grant funds.

The Regional Planning Council contracted with each of the local jurisdictions to perform various elements of the project control program. The Regional Planning Council also contracted with the State of Maryland Water Resources Administration, to conduct non-point sampling program and to provide liaison between the state "303" Basin Plan work and the Regional Planning Council's "208" program. In addition, a contract was awarded to the U.S. Soil Conservation Service to provide accurate estimates of soil erosion in the region.

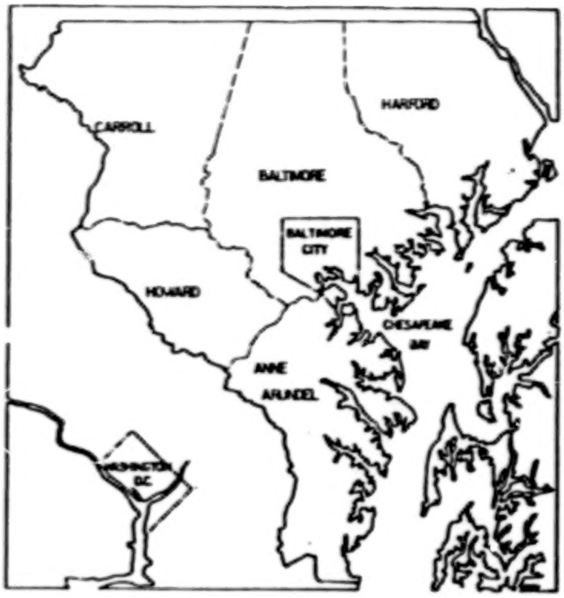

CARROLL
BALTIMORE
HARFORD
BALTIMORE CITY
HOWARD
CHESAPEAKE BAY
ANNE ARUNDEL
WASHINGTON D.C.

FIGURE I
AREA COVERED BY BALTIMORE RPC

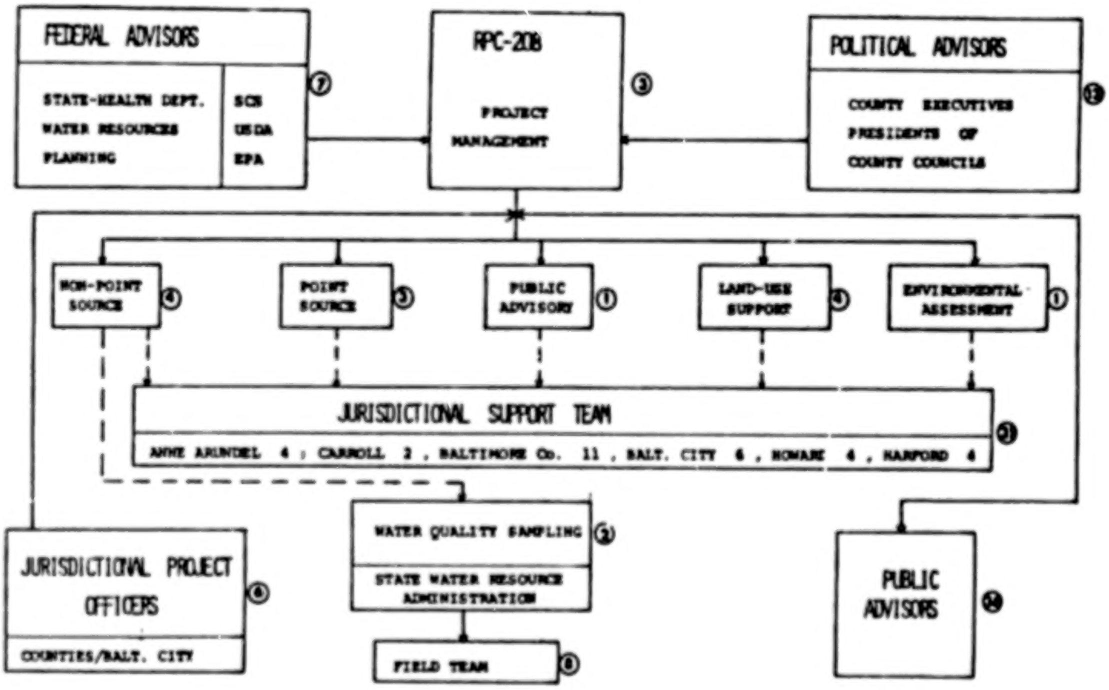

FEDERAL ADVISORS
STATE-HEALTH DEPT.
WATER RESOURCES
PLANNING
SCS
USDA
EPA
⑦
RPC-208
PROJECT MANAGEMENT
③
POLITICAL ADVISORS
COUNTY EXECUTIVES
PRESIDENTS OF COUNTY COUNCILS
⑬
NON-POINT SOURCE
④
POINT SOURCE
⑤
PUBLIC ADVISORY
①
LAND-USE SUPPORT
④
ENVIRONMENTAL ASSESSMENT
①
JURISDICTIONAL SUPPORT TEAM
ANNE ARUNDEL 4 ; CARROLL 2 , BALTIMORE Co. 11 , BALT. CITY 6 , HOWARD 4 , HARFORD 4
㉛
WATER QUALITY SAMPLING
②
STATE WATER RESOURCE ADMINISTRATION
FIELD TEAM
⑧
JURISDICTIONAL PROJECT OFFICERS
COUNTIES/BALT. CITY
⑥
PUBLIC ADVISORS
⑭

FIGURE 2
STRUCTURE FOR THE RPC-208 PROJECT

The entire work program is being carried out under the direction of the Regional Planning Council's "208" staff. Each of the local jurisdictions participating in the areawide plan also has a "208" staff headed by a project officer. There are a number of subcommittees comprised of members from the RPC "208" staff and the local jurisdiction's "208" staff. Each of these subcommittees meets on a regular basis at least once a month to develop the methodology for carrying out the work and monitoring the progress of the various elements of the respective section.

A Public Advisory Committee (PAC) composed of interested citizens and a Technical Advisory Committee (TAC) composed of technical people provide input to the RPC and local jurisdiction's "208" staff. A coordinating committee composed of elected officials from each jurisdiction sets the general policy and all program outputs are subject to the approval of this committee.

The basic requirements of this initial phase in the "208" planning process were: 1) to assess the present state of pollutant loads and pollution in the region identifying areas of criticality; 2) to develop techniques for quantifying the effect of various land uses on pollutant inputs to the receiving waters; 3) to predict the possible future growth of the region and its effect upon the key population and land use parameters which impact pollutant levels; and 4) to develop alternative structural and non-structural procedures to mitigate and control waterborne pollution to cost-effectively meet the EPA standards and guidelines. The development of an accurate, spatially-distributed data base is a key element to the successful operation of the "208" planning process.

The paucity of accurate data on land cover, water quality, and water quantity has made the technical aspects of the program extremely difficult. Conventional reliance on "black-box" models relating the water quantity and pollutant load outputs to precipitation inputs are neither reliable nor cost-effective. Simple "hand-type" computations made without taking into account the actual and current land cover can produce an unacceptably high error level. However, due to the large areas under consideration and the high cost per drainage area for even the simpler models, greater reliance on an accurate measurement of surface cover and estimation of hydrologic properties therefrom is required.

Under direction of the RPC and with MSFC concurrence, ECOsystems applied LANDSAT data for 1975 and the previously developed hydrologic model to the estimates of pollutant loads in the Magothy Basin. The Magothy is one of the three prototype basins selected by the RPC to develop techniques for region-wide pollutant load assessment. The following report details the application of the LANDSAT techniques to pollutant estimation in the Magothy.

IV. THE USE OF LANDSAT DATA IN THE "208" PLANNING PROCESS

Non-point source pollutant loads are dependent upon the hydrologic response of an area and the pollutants incorporated in and upon the surface of the area. Both the hydrologic response and pollutant accumulation are related to the nature and distribution of the land cover.

Comprehensive data bases do not exist at present for specifying the exact cover of the land surface at a resolution sufficiently small to accommodate existing data on soils and sediment. Conventional land use maps do not have the resolution required to assess pollutant loads from individual small watersheds. The LANDSAT 70m pixel (1.1 acres) is sufficiently small, in most cases, to permit land cover accuracies commensurate with the estimates of pollutant loads.

A basic land use inventory is maintained by the Regional Planning Council updated to 1973. Local zoning boundaries are also available, giving a composite representation of land use and zoning, albeit somewhat dated. This land use inventory does not comprehensively yield land surface cover.

The land use data is currently being updated, reviewed, and validated by "208" staffs and made available for use in "208" planning. This inventory includes areas classified in the following categories: residential, commercial, industrial, institutional, open-space, agricultural, semi-public and military.

In addition to the urban land use inventory, other data sources being utilized in the "208" planning process include current building permits, classified as residential (single family and multi-family) and non-residential, summarized by small planning districts; an inventory of all land subdivisions in the region since 1970; and electric meter connection data, by 1/4 square mile grids, provided semi-annually.

Regional "208" planning requires that the RPC and participating local governments upgrade their land use information data handling capability. Data files are now being created in digitized formats that enable computer mapping and graphic displays which expand land use analytic capability. Data files are being created for inventories of vacant land within planned sewer service areas, zoning restrictions, existing urban land uses, and other data on the region's land.

Initial results of the application of computer classified LANDSAT data at RPC, while encouraging, did not yield accuracies commensurate with the program requirements for the small hydrologic basin levels.

A land cover classification by computer was performed at RPC of the Rhode River Estuary, in Anne Arundel County, Maryland. Ground truth land cover data were supplied by the Smithsonian Institute Chesapeake Bay Center for Environmental Studies (CBCES). The Chesapeake Bay Center's review provided land cover data for nine small sub-watersheds of the Rhode, ranging from 15 to 660 acres in size. The CBCES staff had complied their land cover data in five classes (forest, old fields, cropland, pasture, and residential land). The fifty LANDSAT classes developed were aggregrated into combined classes for comparison. Differences between the CBCES and RPC results varied, depending on the class type, for each watershed. The weighted average difference between the two data sources was 32 percent, not considered sufficiently accurate for the "208" application.

It was noted that the LANDSAT classifications used in the comparison were early April vintage, compiled prior to an exhaustive reclassification of agricultural lands done in cooperation with the Baltimore County Agricultural Extension Service and Soil District Conservationists. The CBCES data was from the late summer and fall of 1975 and represented photointerpretation amended by field checks.

Following additional modification of the LANDSAT signatures, a few locational errors were corrected. The weighted average difference between the two data sources was revised to 20 percent using the revised signatures. The twenty percent difference, however, was still seen as unacceptable in view of the modeling efforts planned and designed around the LANDSAT classifications. The required error limits for individual classes are of order 5-10% for sub-watershed areas of 1,000 hectares. These error bounds are required to maintain final estimates of pollutant loads in the range of 15 to 20% over the entire region. Subsequent adjustment of signature mixes brought the computer classifications within acceptable bounds of approximately 8%.

Figure 3 indicates classification error bounds and the performance of the RPC computer-only classification schemes. In the individual sub-basins the classes considered were: land in crops, pastures, woodland, bare soil, and urban usage.

There are two types of requirements for land cover classification for the RPC's "280" project. Aggregate land cover statistics for water supply, urban storm flow, and estuary pollution are required for the three large watershed prototype areas which comprise 19% of the total area and which typify critical water quality problems in the area.

The statistics derived for each of these relatively large watersheds will be used as inputs to runoff models. The estimation of the direct runoff is crucial to the determination of total pollutant loads and for the estimation of the first flush phenomena. Since the areas of the prototype watersheds are relatively large (>10,000 acres), the requirement for class accuracies of 5% does not impose a severe constraint. Subsequent alteration of the signatures has resulted in acceptable accuracy from computer classification of LANDSAT for the larger hydrologic basins.

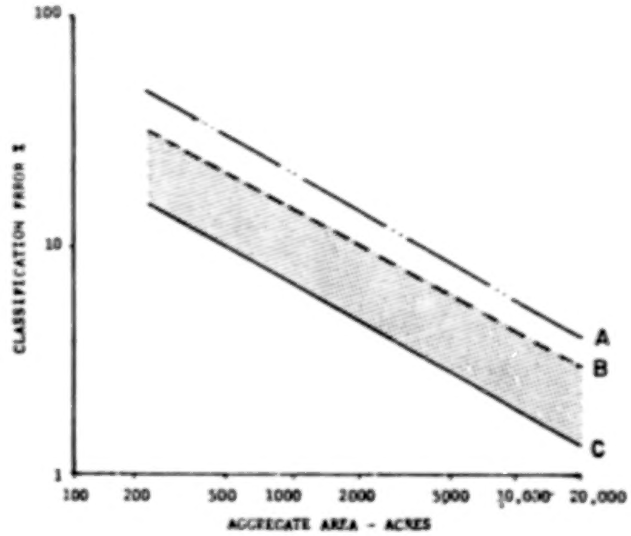
The second requirement is far more stringent and affects a far greater proportion of the area, about 80% of the total. During the early part of June, 1977, it was indicated by RPC that the LANDSAT data could be given a much more extensive role than orginally planned if the accuracies for small areas could approach the requirements indicated in Figure 3.

High accuracies are required for the small areas since the pollutant loads are estimated from correlations with in-situ measurements related to specially selected small, homogeneous areas. The pollutant loads are directly estimated from correlations with the in-situ ground sampling sites illustrated in Figure 4. It is estimated that correlations would exhibit one sigma variance of the order 10-20% given perfect information on land cover. In order to minimize the error contribution from land classification, this requires that small area land classification errors of less than 5-10% be maintained.

Techniques for improving the small area results were required in order to apply LANDSAT data.

FIGURE 3

LAND COVER CLASSIFICATION REQUIREMENTS

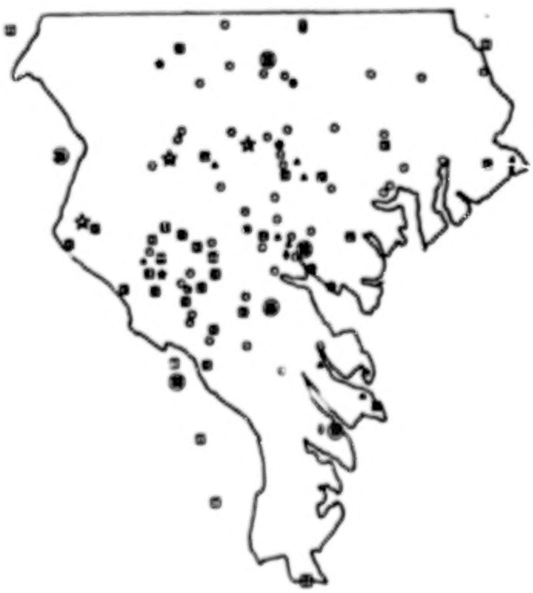


LEGEND:

A - Results of Computer Classification at RPC
B - Upper bound of Acceptable Accuracy
C - Desired Accuracy
▯ - Acceptance Range of Classification Error

FIGURE 4

NON-POINT SOURCE — WATER QUALITY SAMPLING LOCATIONS



SOURCE: REGIONAL PLANNING COUNCIL
BALTIMORE, MARYLAND

SCALE 1 : 920,000

	NO PRECIPITATION GAGE	NON-RECORDING PRECIPITATION	NON-RECORDING GAGE & PRECIP QUALITY	RECORDING GAGE	RECORDING GAGE & PRECIP QUALITY	RECORDING GAGES
RECEIVING WATER STATIONS	○	⊙	◑	⊖	●	
SMALL WATERSHEDS						
URBAN						
RESIDENTIAL	△	▲	▲	▲	▲	
COMMERCIAL	♦	♦	♦	♦	♦	
INDUSTRIAL	●	●	●	●	●	
AGRICULTURAL	☆	☆	☆	★	★	
PRECIPITATION						
QUANTITY	□	◫	◧	⊟	■	⊠

V. APPLICATIONS OF OPTICAL ANALYSIS TECHNIQUES TO LAND COVER CLASSIFICATIONS FOR NON-POINT SOURCE POLLUTANT LOAD ESTIMATION

During June, 1977, an initial presentation was made by ECOsystems personnel to the responsible planners and engineers at the RPC. The presentation described the utility of LANDSAT data for the determination of hydrologically important land cover classes for single season and seasonally changing features. Demonstrated accuracies for classification of 95% (5% error) for small watershed areas, typical of those of importance to the Baltimore RPC area, were of immediate interest. The correlation of the LANDSAT derived information with important hydrologic parameters governing overland flow was also demonstrated. These included the determination of land use classifications and the derivation of Manning's "n" from satellite imagery as performed in earlier phases of NAS8-30539.

In order to confirm the utility and accuracy of the optical analysis technique for use in non-point sources pollution estimation, it was mutually decided to perform a demonstration test on some small watersheds located throughout the Baltimore region. The Rhode River watershed was selected because of the computer classification data effort and ground truth data available. Two other watersheds, in Carroll and Howard County respectively, were also selected to prove the extendability of results.

5.1 Demonstration of Land Cover Classification using Optical Overlay for Small Test Areas in the Baltimore Region

The optical overlay procedure employed determines land cover classification from LANDSAT using USGS topographic maps as base maps and utilizes aerial photographs for ground truth verification.

Three-band combination color diazos are used in the analysis of land cover. Spectral Band 5 (0.6-0.7 µm) is encoded in magenta, Band 7 (0.8-1.1 µm) is encoded in cyan and Band 4 (0.5-0.6 µm) in yellow. The colors employed are selected to maximize visual discrimination among three bands. The cost of a diazo composite, exclusive of the price of the original imagery, is about one dollar.

Since the diazo film is not color stable when exposed to high intensity projection lights for extended periods, the composites were rephotographed on color slide film. The recent introduction of new colorfast diazo film, however, can obviate this step in the future.

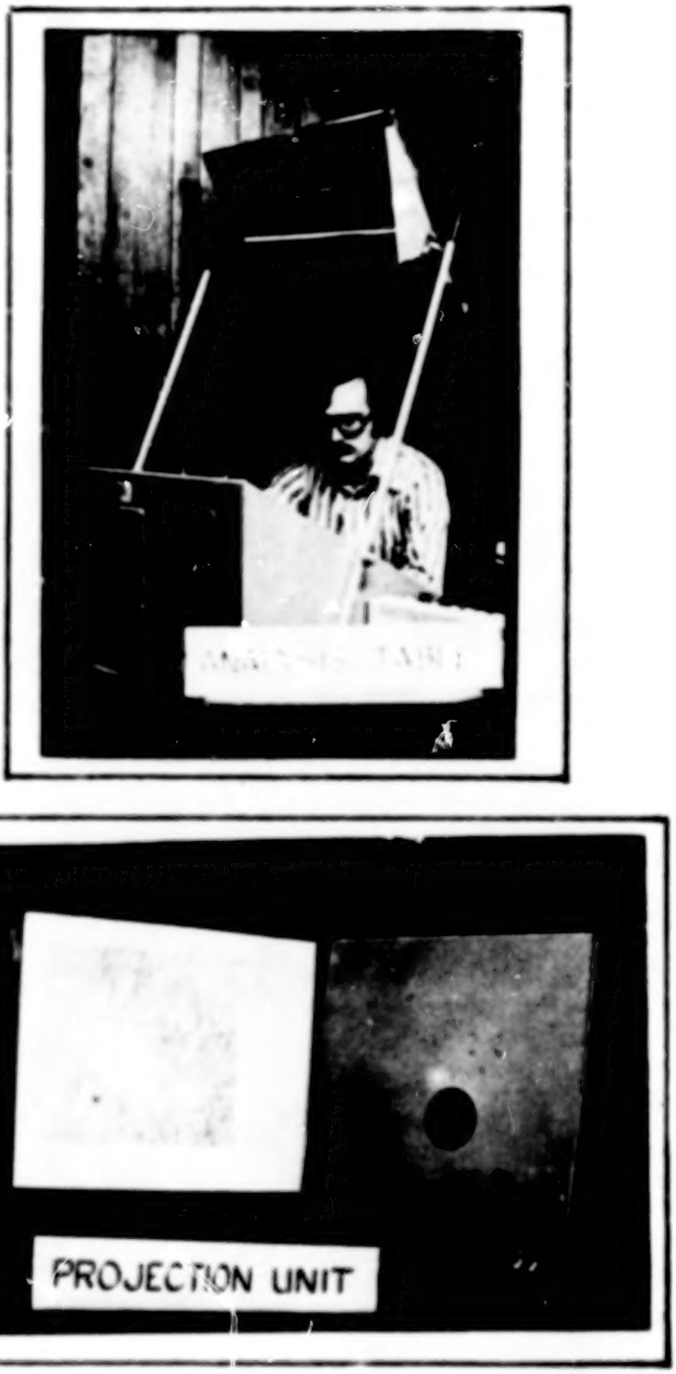
Visual interpretation of LANDSAT imagery is significantly improved by the use of multi-temporal imagery. The accurate identification of such themes as agricultural usage depends upon the observation of their behavior throughout the growing season. LANDSAT land cover analysis was performed using multi-temporal images.

The ECOsystems Universal Image Analyzer, shown in Figure 5, was used. Projected images are reflected onto a work table from an overhead mirror. Electronic controls at the table allow changes in magnification and position of the image. Typically, the projected image is overlayed on a map of known scale, such as the USGS 7 1/2 minute quad sheet (1:24000 scale).

The boundary of the watershed of interest is traced from the USGS map. Land cover is interpreted from the reflectance characteristics of the MSS bands, as determined by the color coding of the composite. Dense vegetation, for example, gives very low reflectance in Band 5. In the projected image, therefore, areas of dense vegetation will appear a dark reddish color; this is due to the magenta

FIGURE 5

ECOSYSTEMS UNIVERSAL IMAGE ANALYZER


ANALYSIS TABLE
PROJECTION UNIT

coding of Band 5 in the diazo composite. Similarly water will appear black, urban areas will generally be white to light blue, grass and pasture will be a lighter red or orange, bare soil will be light blue to blue, and agricultural areas will vary between blue and light red depending upon the stage of growth of the crops. When the total classification is complete, the areas of each class is planimetered.

5.2 Land Classification of the Rhode River Estuary Test Area

The optical classification procedure was applied to the Rhode River Estuary using LANDSAT imagery from April and October, 1973, and February, 1974. The Rhode is a tributary of the Chesapeake Bay located in Anne Arundel County, Maryland as shown in Figure 6. The test area covers about 3200 hectares and is predominantly rural with some residential development. Other land uses present include forests, grass/pasture and agricultural areas. The 1:24000 USGS topographic map was used to establish the ridge line of the basin.

Color infrared aerial photography at 1:60000 scale provided by the RPC served as the ground truth. These photos were taken in September, 1970, but were deemed accurate for the purposes of this analysis as the area was not subjected to any significant development.

Black and white 1975 LANDSAT originals were combined into diazo color composites with Band 4 in yellow, Band 5 in magenta, and Band 7 in cyan.

Nine small training areas were isolated and an overlay of their location was made. The sequential color of each training area was noted. The image with the highest discriminability for each class was noted and a preliminary classification of the whole basin was made. Successive images were then used to refine the initial classification by the multi-temporal overlay procedure.

The area of each land cover class was then measured by planimeter and compared to a ground truth map derived from the aerial photographs. Table I shows the results of this comparison. The average weighted inventory error was 5.5%.

These results are consistent with earlier findings in that the inventory errors are small except in classes with very small absolute areas, e.g., cropped areas, developed areas and surface water. The accuracies were commensurate with the RPC requirements and represented an improvement over computer-only classifications.

5.3 Land Classification of the Howard County Watershed Test Area

The Howard County site shown in Figure 7 comprises 442 hectares of land; the primary land cover class is grass/pasture. About three percent of the basin has been developed. It drains into the Little Patuxent River, which in turn flows into the Chesapeake Bay.

The procedure applied in the analysis of this watershed was the same as that described for the Rhode River. Because of its small size, no sub-site analysis was attempted. 1:60,000 color infrared aerial photographs were used for ground truth.

The LANDSAT images used were from April and October, 1973, and February, 1974. By sequential projection of each scene, it was determined that only three cover classes were present: forest, pasture/grass, and residential. Forest was segregated using the February

FIGURE 6

LOCATION OF THE RHODE RIVER TEST SITE

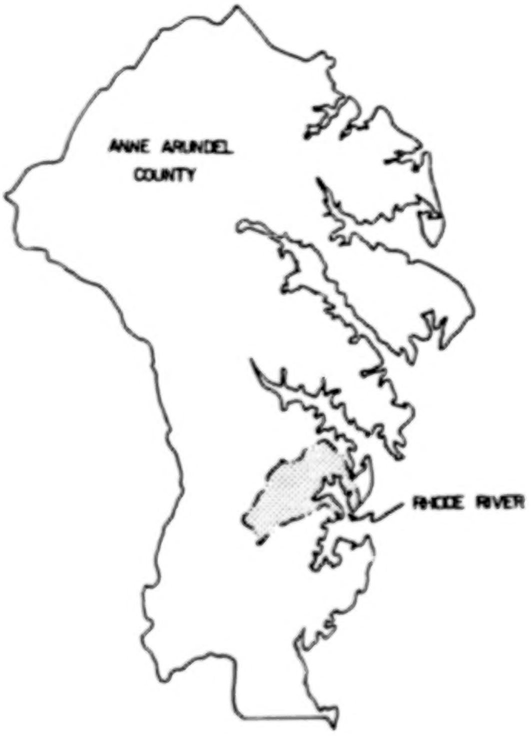


TABLE I

RHODE RIVER WATERSHED
RESULTS OF SATELLITE LAND USE CLASSIFICATION

CLASS	% OF TOTAL AREA (MEASURED FROM AERIAL)	AREA (HECTARES) (AERIAL)	% OF TOTAL AREA (MEASURED FROM LANDSAT)	AREA (HECTARES) (LANDSAT)	% ERROR
Forest	55.1	1,761.5	57.1	1,825.5	3.6
Fields	36.3	1,160.5	38.0	1,214.9	4.7
Cropped Areas	1.0	31.0	0.5	16.0	50.0
Developed	6.6	211.0	4.4	140.7	33.3
Water	4.0	127.9	--	--	—

WEIGHTED AVERAGE ERROR - 5.5%

FIGURE 7

HOWARD COUNTY SITE

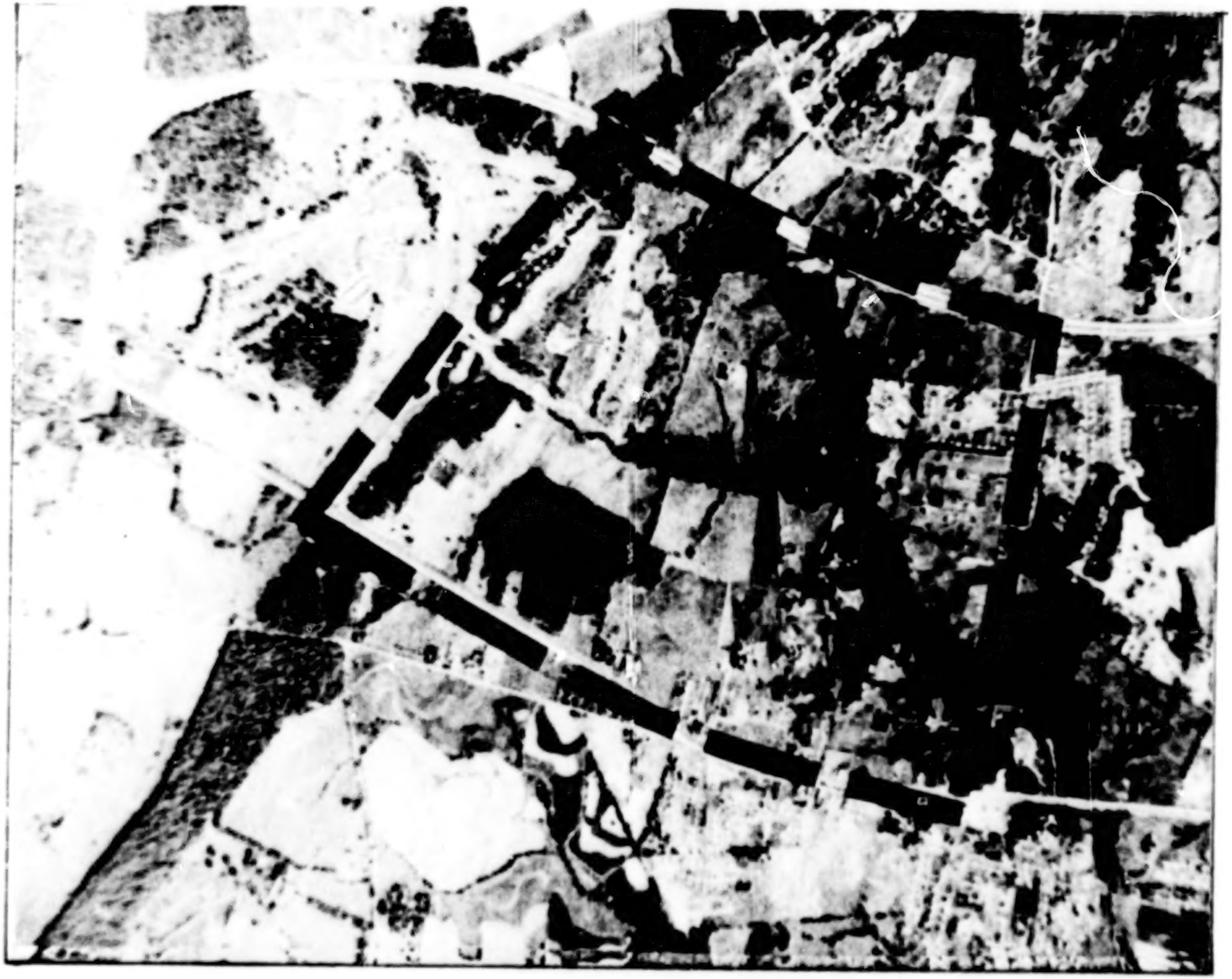


image. Identification of the other land cover classes was accomplished by using the other images in a multi-temporal sequence.

Measurements of the land cover classes were performed and compared with the measurements of comparable classes from the aerial photographs. The results are shown in Figure 8 and Table II. The weighted average error was 2.4% which met the classification criterion established by the RPC.

5.4 Land Classification of the Carroll County Test Area

The Carroll County watershed is located in an agricultural area west of Westminster, Maryland. This site, shown in Figure 9, is predominately agricultural. Of its 650 acres, about 600 are in fields and pastures; the remaining acres are forest. The residential area within the watershed is extremely small. The average size of fields within the site area is about nine acres.

The satellite images were prepared as composites with Band 4 in yellow, Band 5 in magenta, and Band 7 in cyan.

The October image was projected and overlayed on a USGS topographic map to set the scale. The color of each individual field was recorded.

This procedure was subsequently repeated for the February, 1974 image. As noted earlier, no ground truth existed for 1973; therefore, an absolute comparison of the satellite and aerial images was not possible, since fields in the area are rotated from year-to-year. The analysis was continued, however, realizing that changes in the field content from 1973 to 1975 might be the source of error.

FIGURE 8

HOWARD COUNTY TEST SITE

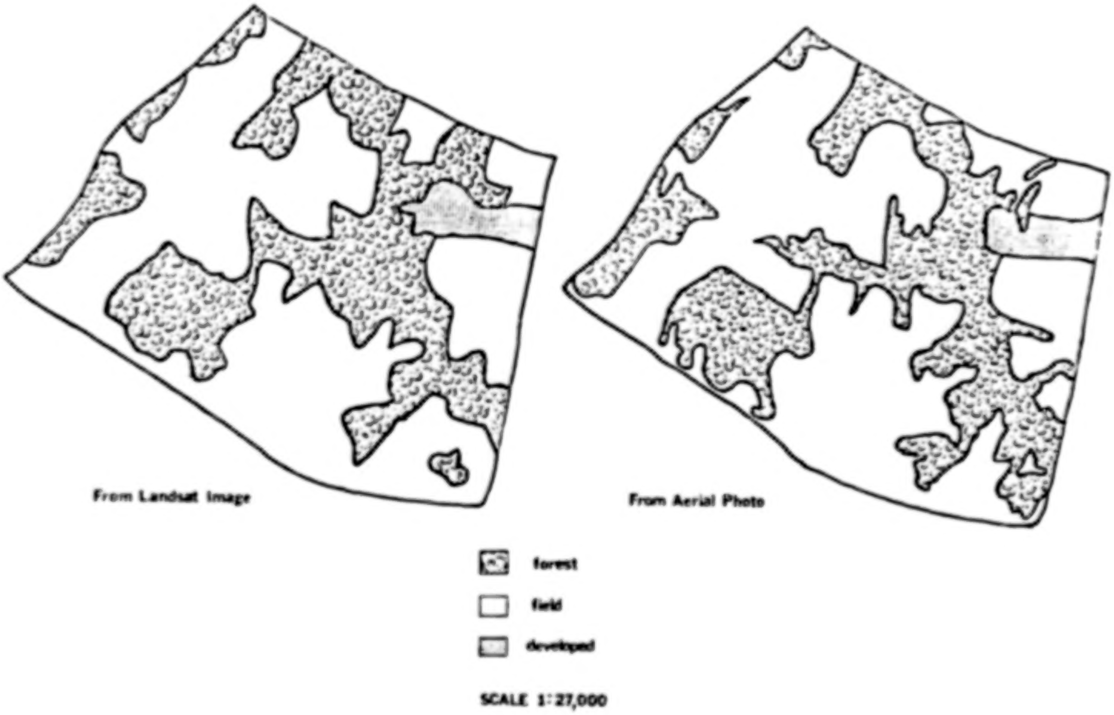

From Landsat Image
From Aerial Photo
forest
field
developed
SCALE 1:27,000

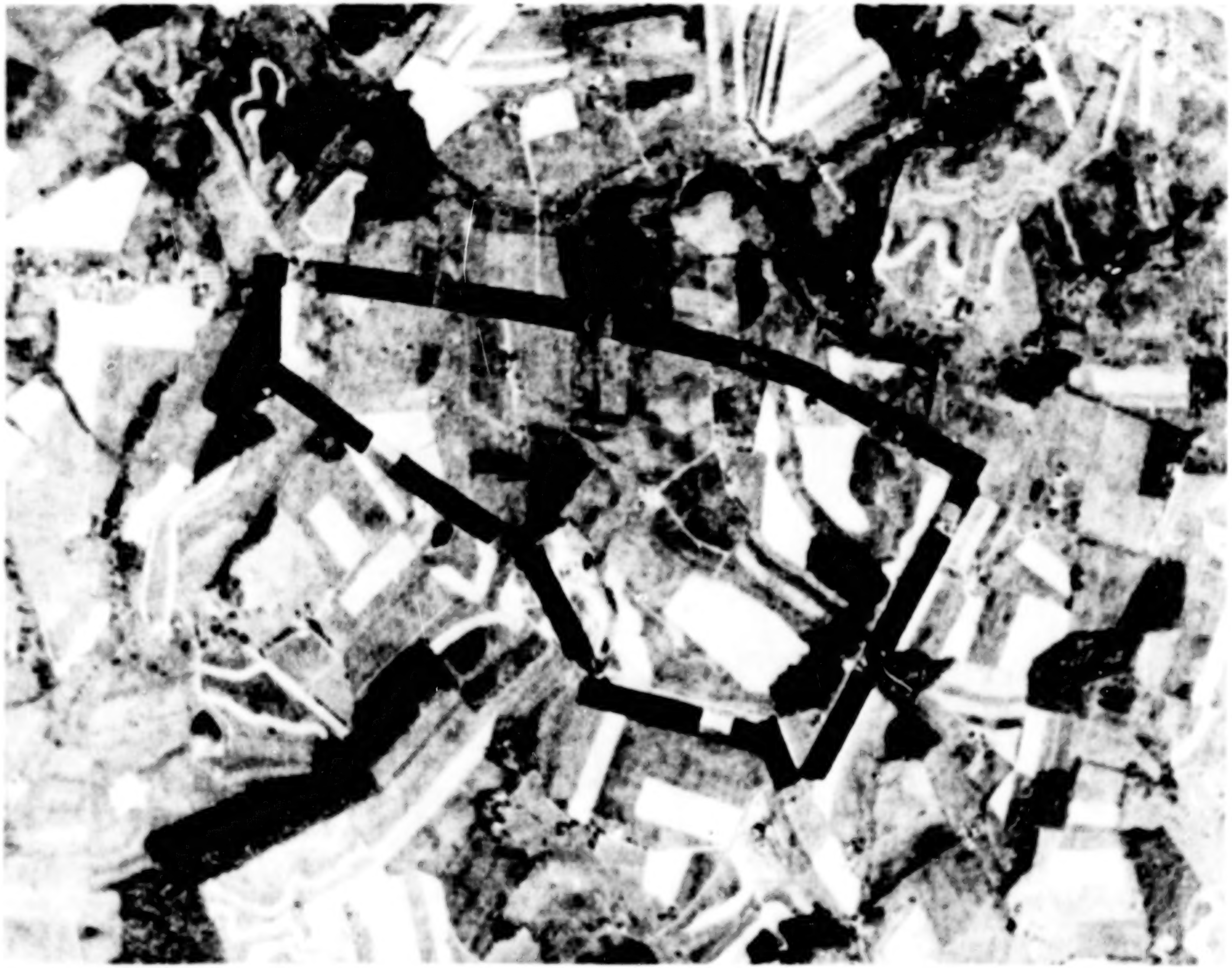
TABLE II
HOWARD COUNTY SITE
RESULTS OF SATELLITE LAND USE CLASSIFICATION

LAND USE CLASS	% OF TOTAL AREA (AERIAL)	AREA-AERIAL (hectares)	% OF TOTAL AREA (LANDSAT)	AREA-LANDSAT (hectares)	% ERROR
FORESTS	35.5	156.9	36.1	159.6	1.7
FIELDS	61.5	271.8	60.3	266.5	1.9
DEVELOPED	3.0	13.3	3.6	15.9	19.5
WATER	-	-	-	-	-

WEIGHTED AVERAGE ERROR = 2.4%

FIGURE 9

CARROLL COUNTY SITE



In examination of the two LANDSAT images, it was noted that two distinct classes of fields were present. Roughly half of the fields underwent a distinct change in color from October to February, i.e., several fields appeared bright orange (indicating dense vegetation) in October and light blue (indicating soil or sparse vegetation) in February. The remainder of the fields remained constant during the season. The former class represented cropped areas while the latter were pastures. The results of the classification are given in Table III and indicated a weighted error of 5% which met the criterion established.

5.5 Conclusions

From the results achieved for the three test basins, it was apparent that overall accuracies from optical analysis are satisfactory for non-point source pollutant assessment. The average inventory error of the three sites was less than five percent. This represents a substantial improvement over the twenty percent errors typical in computer-only analysis. These results permit the computation of surface related hydrologic parameters at desired accuracies.

The three hydrologic parameters of importance to the pollutant load estimates are: surface friction of the overland flow areas of the watershed (Manning's "n"), estimation of the seasonal values of the ratio of direct-to-delayed runoff due to a given storm event, and the impervious/pervious fractions of the watershed. All three of these parameters play key roles in the determination of non-point source pollution estimates for the non-prototype areas and are amenable to direct estimation from satellite imagery.

TABLE III

CARROLL COUNTY SITE

RESULTS OF SATELLITE LAND USE CLASSIFICATION

LAND COVER CLASS	% OF TOTAL AREA (aerial)	AREA (hectares) AERIAL	% OF TOTAL AREA (LANDSAT)	AREA (hectares) LANDSAT	% ERROR
CROPPED AREA	44.6	116.0	42.1	109.5	5.6
PASTURES	55.4	144.0	57.9	150.5	4.5

WEIGHTED AVERAGE ERROR = 5%

Optical LANDSAT image analysis was also cost effective. Direct comparison of the cost per unit area was not possible since detailed records of the alternatives were not available from the RPC. The projected costs from the ECOsystems experience of \$0.50/km^2 would yield a total cost of \$2500 for the RPC area, a figure which was well received by the RPC personnel.

There is an inherent interest at RPC to use LANDSAT type information in a simple and direct way. So far the problems of limited accuracy, cost of acquisition of ground truth, and difficulty in signature extension using conventional LANDSAT computer classification techniques have limited the utility of the LANDSAT data. The application of the simple optical techniques appears to have potential for upgrading the utility of LANDSAT. An explanation of how to interpret LANDSAT images using these procedures was made to the RPC personnel. The optical technique permitted direct interpretation by the multi-disciplinary RPC team with enhanced information return. The low cost of the images permits expanded analysis of seasonal land cover which closely matches the requirement for incorporation into the modeling of pollutant loads associated with critical runoff events.

Based on the results achieved for the test sites and this positive reception by the RPC, the complete land cover analysis and pollutant load assessment of the Magothy River was undertaken. The procedure applied and the conclusions reached are reported in the next section.

VI. ESTIMATION OF NON-POINT POLLUTANT LOADS FOR THE MAGOTHY BASIN USING LANDSAT DERIVED DATA

The estimation of non-point source pollutant loads from representative watersheds is a key element in RPC's approach to areawide wastewater management for the Baltimore Region. The anticipated high cost of modeling each of the more than 100 water quality districts comprising the region required that the RPC select a limited number of "prototype" basins which were adjudged to be representative of the region and from which the total non-point source loads of the non-prototype areas could be estimated.

One of the three prototype regions selected by the RPC was the Magothy River basin located in close proximity to the ECOsystems facility at Gambrills, Maryland. The Magothy is a 8600 hectare watershed which drains into the tidally dominated Magothy River as shown in Figure 10.

The ECOsystems model ECHOS* was used to calculate annual pollutant loads for the Magothy. The model computes overland flow from individual rain events and stores the output as flow versus time. The process is repeated for each sub-basin. Subsequently, the model routes the output of the appropriate sub-basin or sub-basins through successive channels until the basin outlet has been reached. Tabular results are prepared giving the time since the start of rainfall, rain and discharge rates, and cumulative rain and discharge. Total discharge for the month is computed and converted to pollutant loads using loading factors determined for the existing land use categories.

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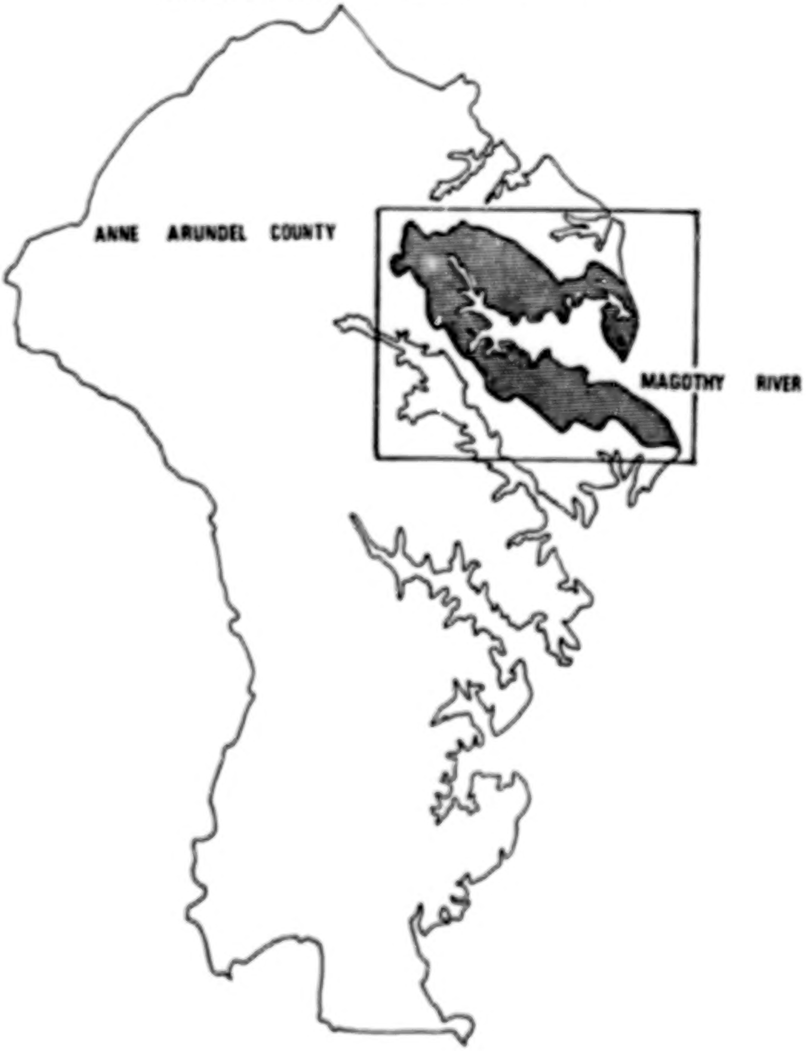
*See Appendix A for a description of the model.

FIGURE 10

MAGOTHY RIVER BASIN


ANNE ARUNDEL COUNTY
MAGOTHY RIVER

The following sections detail the essential elements necessary to develop and exercise the pollutant load estimation model and indicate the role of LANDSAT data and the results obtained.

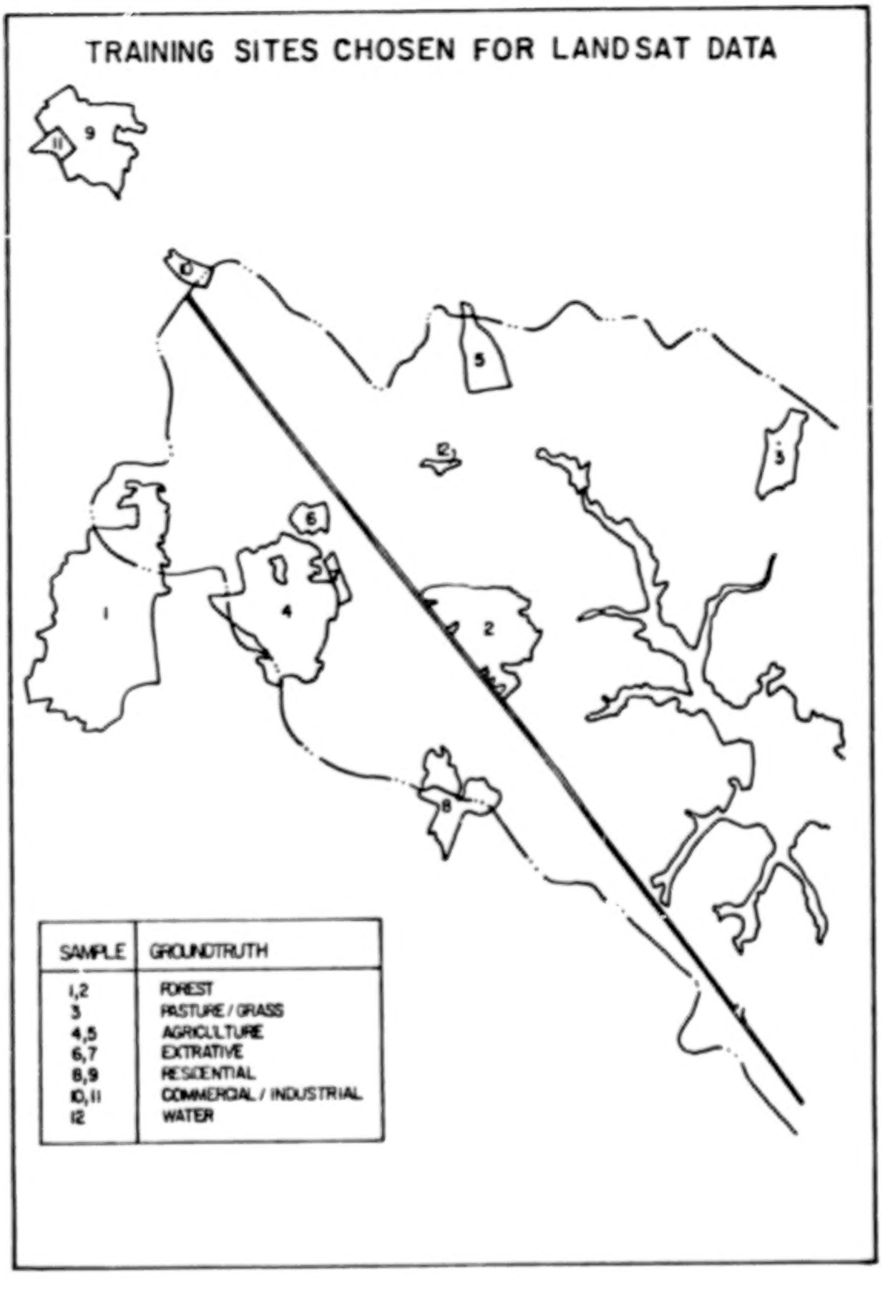
6.1 Land Cover Analysis from LANDSAT Data

The land cover classification of the Magothy River Watershed was performed using the optical techniques described previously. Satellite imagery was processed into color slide form. Seven general land use classes were desired: residential, commercial/industrial, extractive, agriculture, water, forests, and pasture/grass areas.

Training sites were selected for each class and constituted about two to three percent of the total watershed. A map was prepared locating the sites and the watershed boundary. It is reproduced in Figure 11.

Each satellite scene was projected onto the location map of training sites and the color for each area was recorded. LANDSAT images of May, August, and October, 1975, February, 1974 and April and October, 1973 were used. The colors recorded for each date are given in Table IV . This information was then used to determine which scenes were preferable for identifying different land use classes. For example, Table IV shows that forest appeared dark in the February, 1974 scene, while potential confusers were lighter. This image was used to segregate forest. Similar logic was applied to separation of the other land use classes. High color contrast in the October 6, 1973 scene allowed the reliable separation of the extractive and commercial/industrial classes. A negative image of October 6 showed water as bright white; it was therefore readily separated.

FIGURE 11



TRAINING SITES CHOSEN FOR LANDSAT DATA

SAMPLE	GROUNDTRUTH
1,2	FOREST
3	PASTURE / GRASS
4,5	AGRICULTURE
6,7	EXTRATIVE
8,9	RESIDENTIAL
10,11	COMMERCIAL / INDUSTRIAL
12	WATER

TABLE IV

COLOR COMPOSITE ANALYSIS: MAGOTHY RIVER BASIN

SAMPLE SCENE	Forest 1	Forest 2	Pasture/Grass 3	Agriculture 4	Agriculture 5	Extractive 6	Extractive 7	Residential 8	Residential 9	Commercial/ Industrial 10	Commercial/ Industrial 11	Water 12
April 9, 1973	Gray	Gray	Lt. Pink	Dk. Pink	Dk. Pink	White	White	Lt. Pink	Lt. Pink	Lt. Blue	Lt. Blue	Blue
Oct. 6, 1973	Red	Red	Lt. Blue	Lt. Blue	Lt. Blue	White	White	Lt. Blue	Lt. Red	Blue	Blue	Black
Oct. 6, 1973	Blue	Blue	Red	Red	Red	Red	Red	Red	Red	Red	Red	White
Feb. 27, 1974	Brown	Brown	Lt. Blue	Lt. Blue; Orange	Lt. Blue; Orange	White	White	Lt. Blue	Lt. Brown	Lt. Blue	Lt. Blue	Black
May 14, 1975	Dk. Orange	Dk. Orange	Blue-Orange	Blue-Orange	Blue-Orange	Lt. Blue	Lt. Blue	Orange	Lt. Orange	Blue	Blue	Black
Aug. 8, 1975	Dk. Orange	Dk. Orange	Orange	Orange	White-Orange	White	White	Orange-Blue	Orange-Blue	Blue	Blue	Black
Oct. 14, 1975	Purple	Purple	Purple	Lt. Blue-Orange	Lt. Blue-Pink	White	White	Purple	Purple	Lt. Blue	Lt. Blue	Black

☐ - INDICATES PREFERRED IMAGE

Table IV indicates that no single image shows agricultural areas in marked contrast with the other classes. It was determined by examination of all the available scences that agricultural areas followed a unique progression of colors: dark pink in April, light blue to white in October, and orange/light blue in February. All areas exhibiting this behavior were then classified as agricultural.

Residential areas were not strongly separable from pasture/grass in any scene. This is due to the low density (2-4 units per acre) of most residential development present. Some of the more densely developed residential areas could be consistently identified; most appeared to be the same as the pasture/grass areas in all scences. The residential class was determined from aerial photography. The use of a hybrid satellite/aerial remote sensing system to derive pollution loads represents a necessary compromise.

On the basis of this technique, the land classification map shown in Figure 12 was prepared. The entire Magothy River watershed was also mapped and classified from the aerial photo. Because of the age of the aerials (September, 1970), imagery from 1975 was acquired from the Baltimore RPC and the ground truth map updated. Alterations were required in ten areas reflecting the post 1970 residential and/or commercial development.

The areas of each land cover class were computed from the aerial and hybrid maps for each of the seventeen subbasins. The results are reported in Table V. The overall classification accuracy of 2.3% is consistent with the other watersheds analyzed and well within the requirement of the RPC. The land use classifications was also used to develop

FIGURE 12

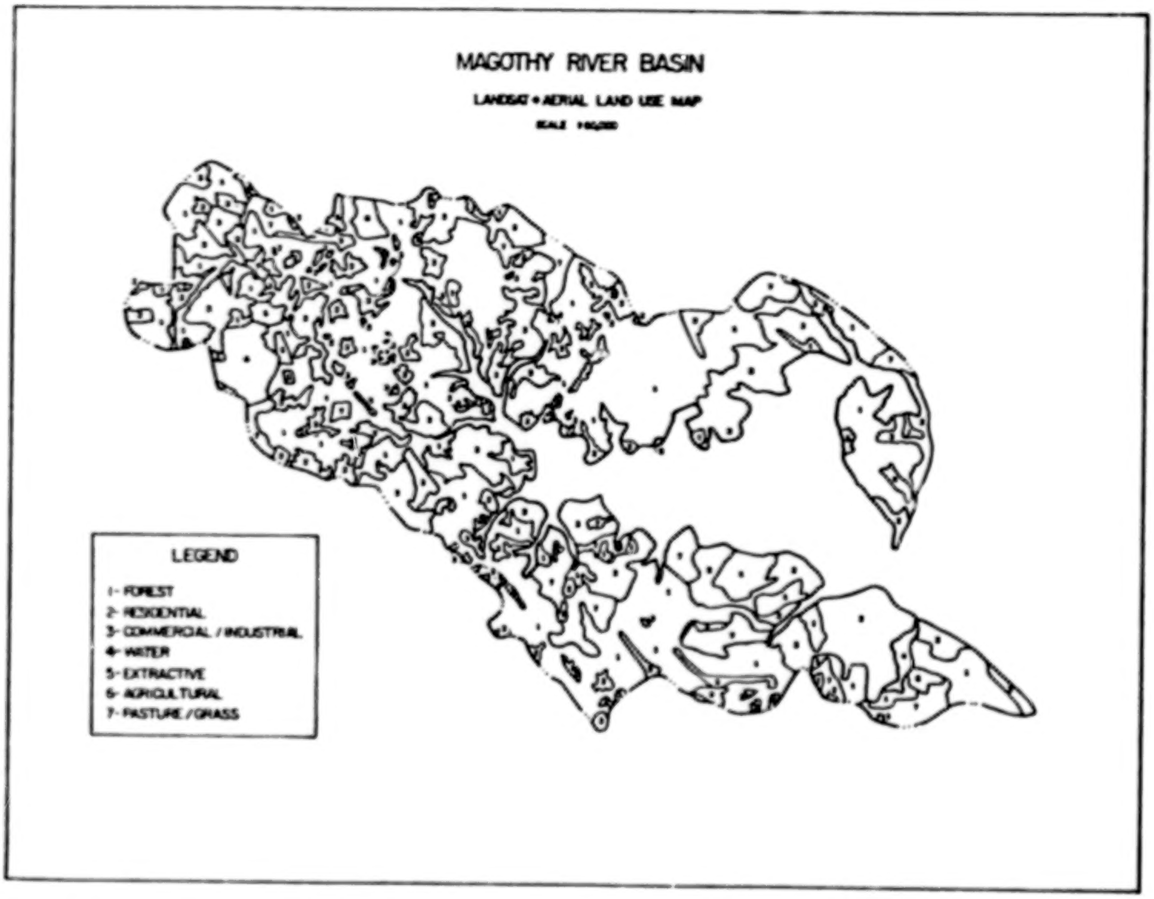

MAGOTHY RIVER BASIN
LANDSAT + AERIAL LAND USE MAP
SCALE
LEGEND
1- FOREST
2- RESIDENTIAL
3- COMMERCIAL / INDUSTRIAL
4- WATER
5- EXTRACTIVE
6- AGRICULTURAL
7- PASTURE / GRASS

TABLE V

LANDSAT & AERIAL CLASSIFICATION OF THE MAGOTHY RIVER

AREA, HECTARES

SUBBASIN	FOREST	RESIDENTIAL	COMMERCIAL, INDUSTRIAL	WATER	EXTRACTIVE	AGRICULTURE	PASTURE, GRASS	TOTAL
1	72,0	25.6	-	18.6	-	-	-	116.2
2	339.2	255.6	-	-	-	-	74.4	669.2
3	281.1	204.5	-	-	-	-	-	485.6
4	237.0	25.6	-	-	-	-	-	262.6
5	474.0	227.7	-	-	-	-	55.7	757.4
6	1279.2	697.1	69.7	5.8	41.8	190.5	86.0	2370.1
7	181.2	51.1	-	-	-	-	-	232.3
8	434.5	209.1	13.9	-	-	-	39.5	697.0
9	106.8	160.3	34.9	-	-	-	-	302.0
10	97.6	41.8	11.6	-	-	-	-	151.0
11	260.1	48.9	20.9	-	-	-	65.1	395.0
12	188.2	165.0	16.3	-	-	-	95.3	464.8
13	300.8	178.9	10.5	-	-	-	67.4	557.6
14	260.3	264.8	25.6	-	-	-	53.4	604.1
15	241.7	162.6	2.3	-	-	23.2	104.6	534.4
TOTAL	4753.7	2718.6	205.7	24.4	41.8	213.7	641.4	8599.3
ERROR	-1.5%	-	-1.9%	-9.6%	-5.2%	-8.9%	+18.9%	

WEIGHTED AVERAGE ERROR = 2.3%

the required hydrologic inputs to the ECHOS model and to assess the pollutant load conversion coefficients for the 17 sub-watersheds.

6.2 Determination of the Rainfall and Runoff Inputs to the Model

Storm generated, non-point source load estimation utilizes the correlation between land cover generated pollutant loads and the volume of runoff. Sediments and sediment-entrained pollutants are carried overland by storm water runoff and deposited into the stream channels. After deposition in the channels, they are transported and altered by channel flow processes to the stream outlet. The process of pollutant delivery to the channel outlet can be simulated by computer models with routines for overland and channel flow, such as the ECHOS model developed under NAS8-30539.

The ECHOS model requires calibration with a small number of actual rainfall and runoff records. Though the Magothy River is not permanently gaged, a limited amount of on-site data was collected by the RPC. Historical and current rainfall records were also available for nearby weather stations.

On-site data were taken for various months during 1977 at three sites: Bay Hills, Severna Park, and Cape St. Clair. Measurements were taken for a total of 80 rainfall events. However, sufficient runoff records existed for only four events at Cape St. Clair: 24 February, 18 March, 2 April, and 25 July, 1977 from which to construct an accurate hydrograph. Rainfall hyetographs and runoff hydrographs for these dates are graphed in Figures 13a, b, c, and d. These graphs show the actual runoff response of Magothy sub-watersheds to actual rain events.

FIGURE 13a

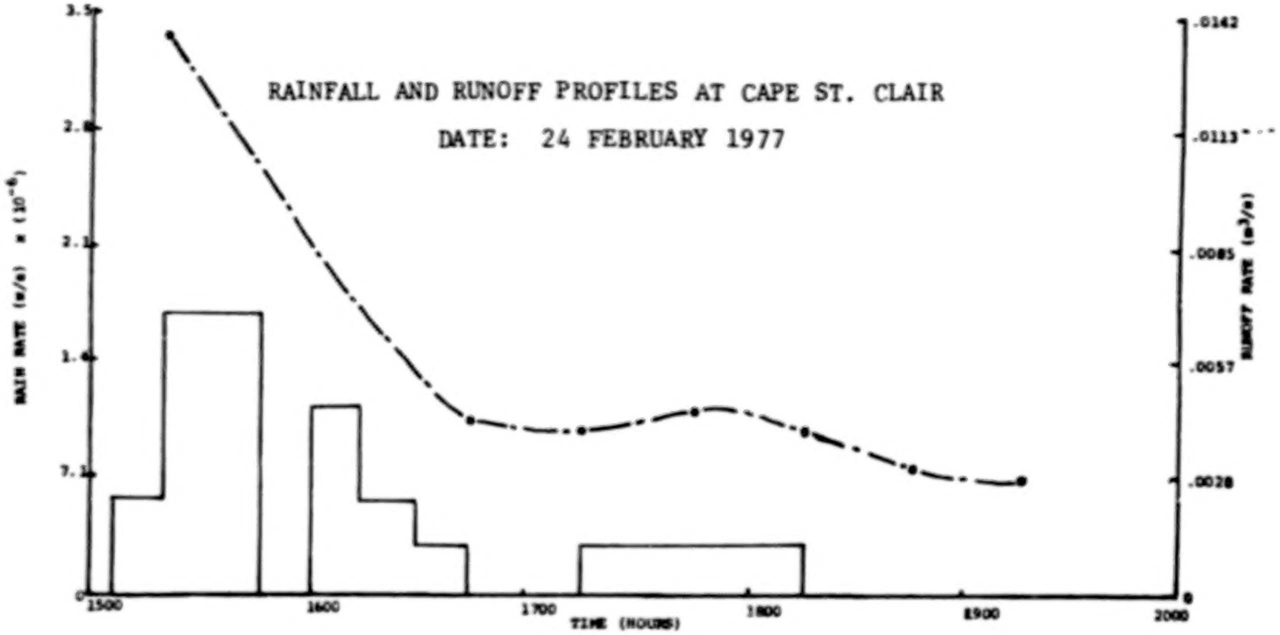


FIGURE 13b

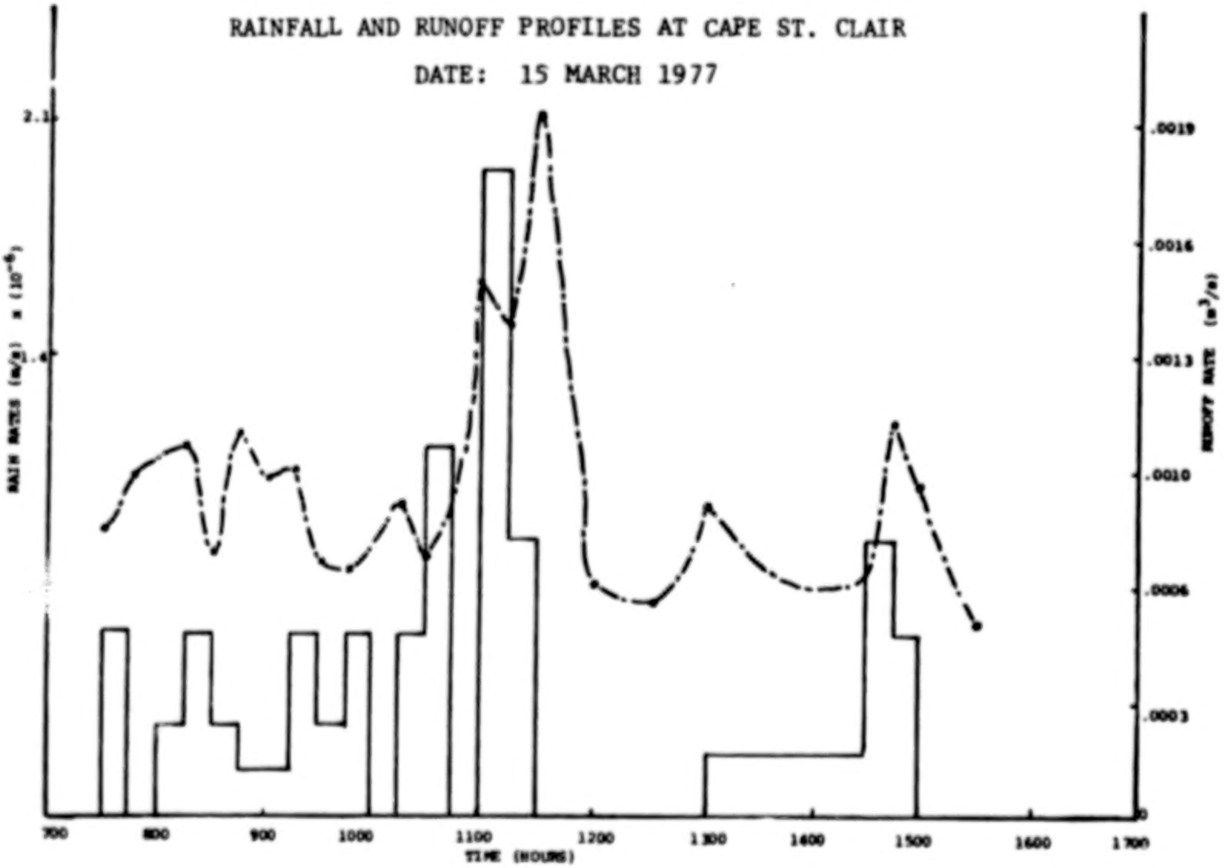
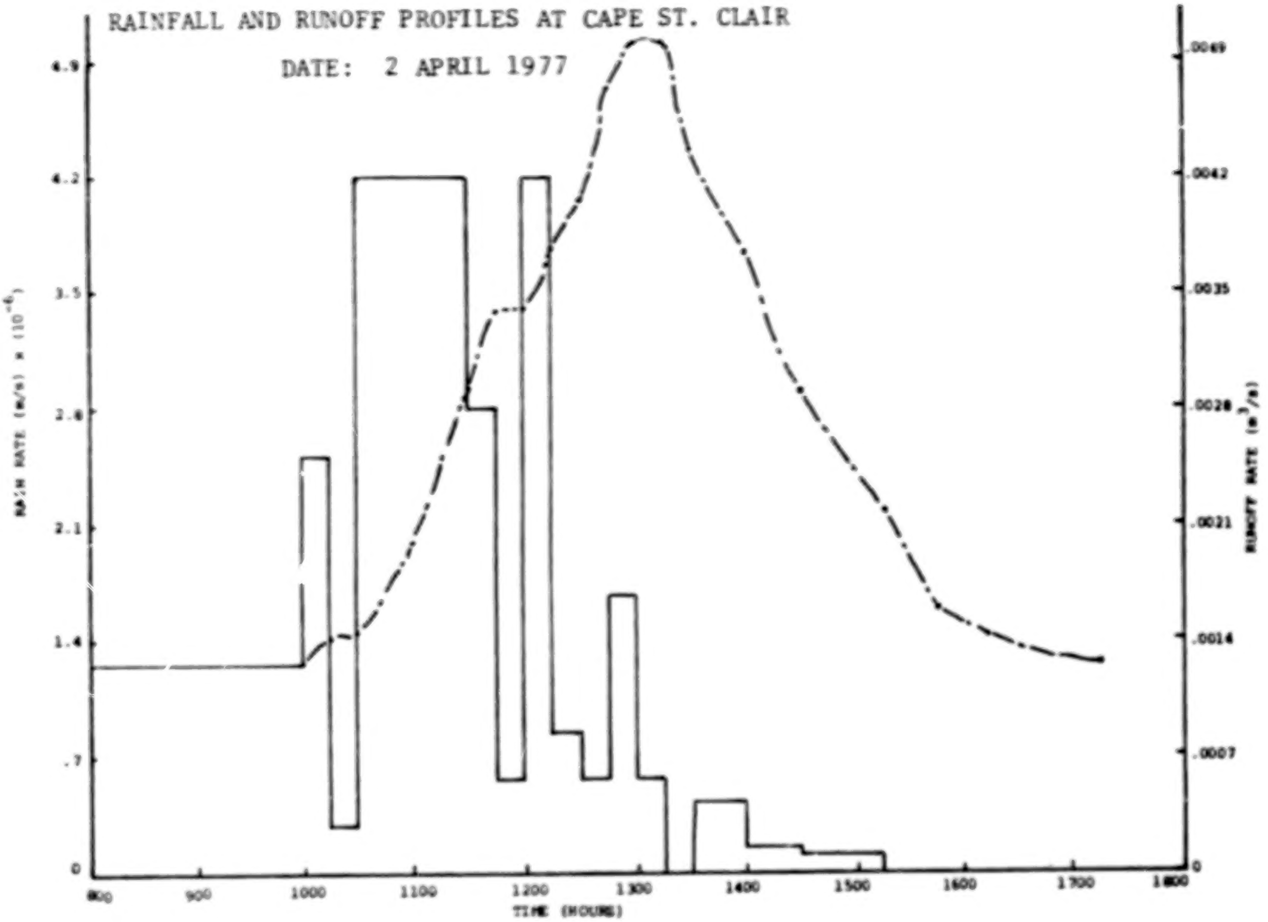


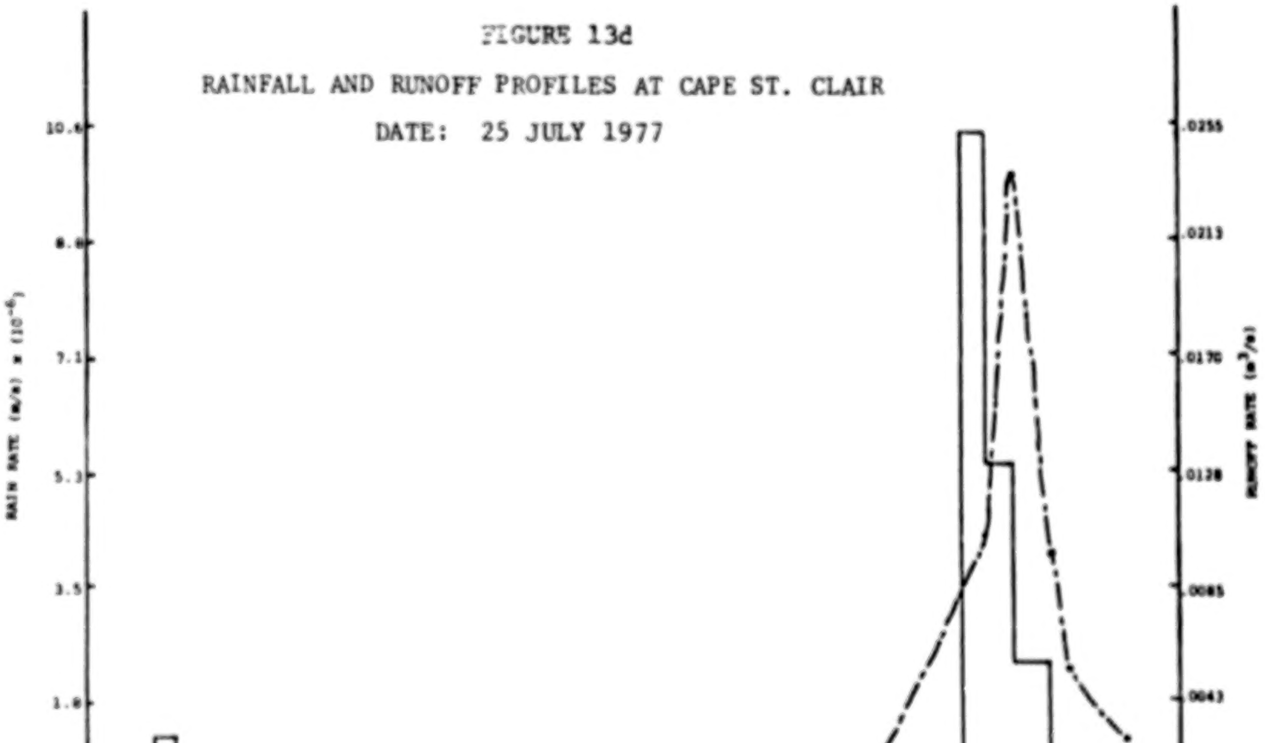
FIGURE 13c



RAINFALL AND RUNOFF PROFILES AT CAPE ST. CLAIR

DATE: 2 APRIL 1977

FIGURE 13d



RAINFALL AND RUNOFF PROFILES AT CAPE ST. CLAIR

DATE: 25 JULY 1977

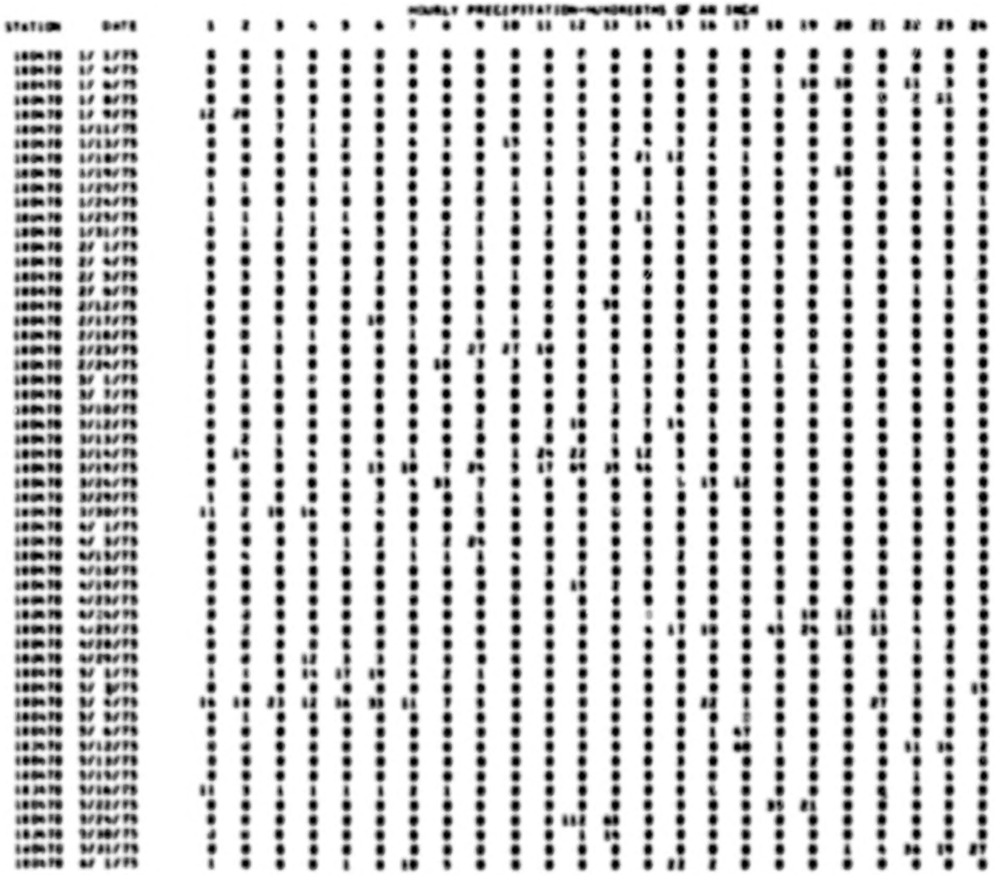
Monthly averages of number of storm events, volume, duration, intensity and time between storms were computed from an analysis of twenty-five years of hourly rainfall records from the nearby NOAA weather station at Baltimore Friendship Airport. Typical rainfall data available from NOAA is shown in Table VI. The raw data were processed by computer to produce a statistical summary. The monthly summary presented in Table VII gives the intensity, volume, duration and time between storms and includes the average, minimum, maximum, standard deviation, variance and C.V. for each parameter. Table VIII summarizes the data from the Table VII and lists the selected parameters of the monthly average rain events to be used in the simulation.

Direct runoff from a storm of a given volume, magnitude and average intensity depends directly upon the distribution of the rain rates over time. Discharge rates and volumes vary with the "shape" of the rain input. Average peak rain rate and average time to peak rate were derived for each month using a large, fifty percent sample of the storms from 1948-1975 and recording the peak rate and time to peak rate. The sample comprised from 100 to 150 storms, depending on the month for the period of record, and were representative of the actual rainfall behavior.

The temporal rainfall profiles were approximated by a series of discrete intervals with total volume, intensity, peak rate, and time to peak equal to the average values adjusted to match the durations and volumes specified in Table VII. The June 1975 profile is shown in Figure 14 along with its discrete approximation as an example of this procedure. The average number of storms expected during each month was computed from the average time between storms and is also given in Table VIII.

TABLE VI

HOURLY RAINFALL DATA: BALTIMORE AIRPORT GAGE FOR THE PERIOD JANUARY - JUNE 1975

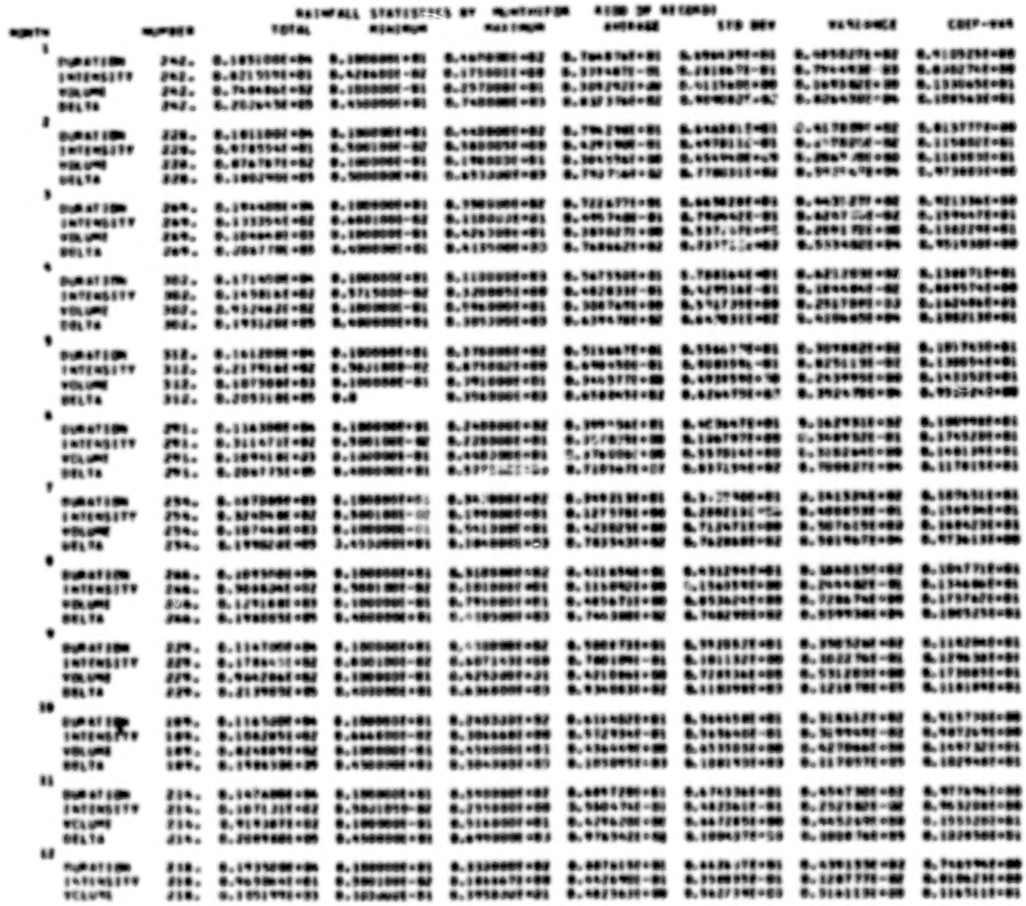


HOURLY PRECIPITATION—HUNDREDTHS OF AN INCH

STATION DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

TABLE VII

MONTHLY STATISTICAL SUMMARY, 1948-1975 FOR THE BALTIMORE AIRPORT RAIN GAGE.



```
                         RAINFALL STATISTICS BY MONTH
MONTH         NUMBER      TOTAL      MINIMUM      MAXIMUM      AVERAGE      STD DEV      VARIANCE      COEF-VAR
```

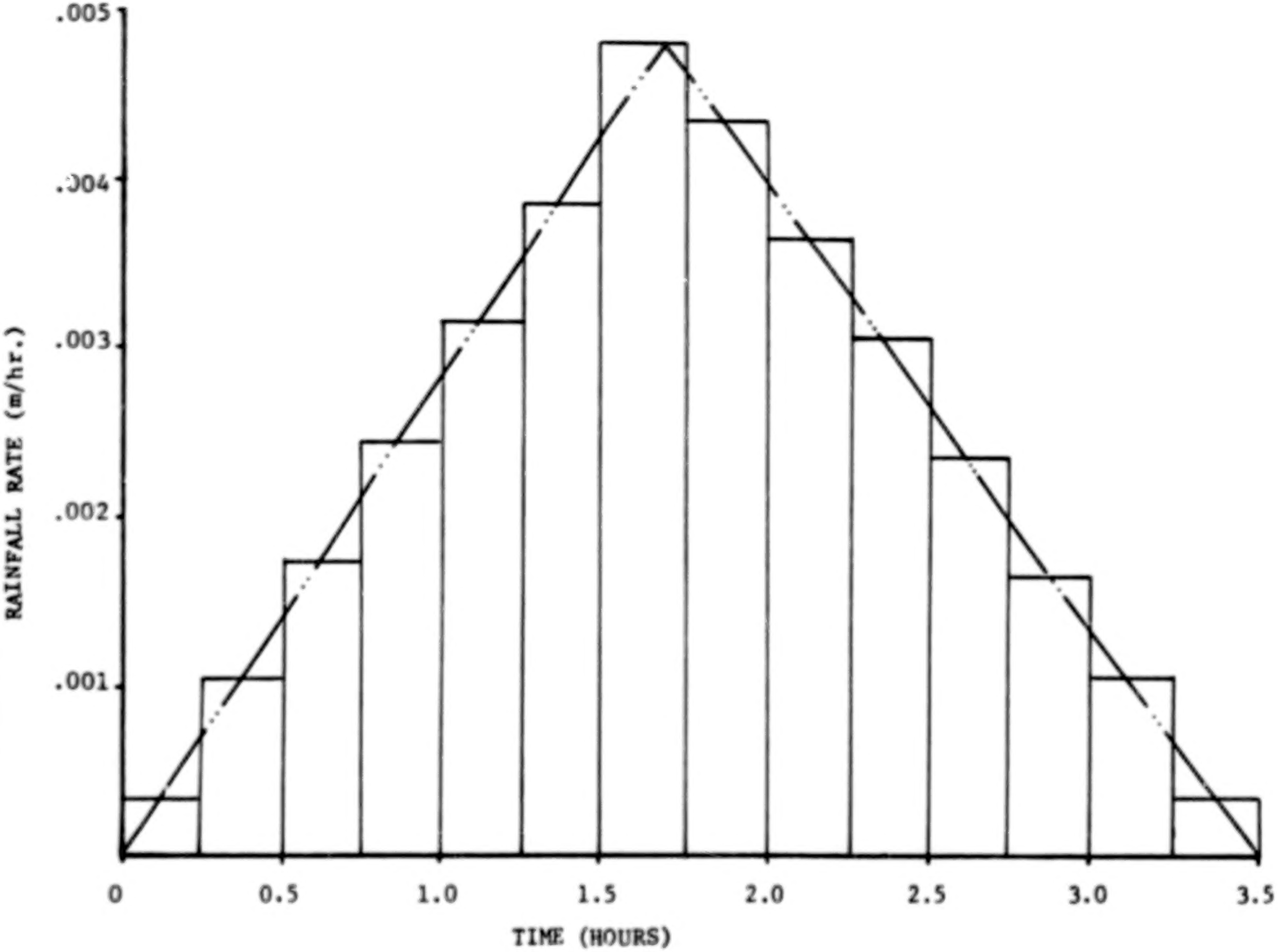
TABLE VIII

SUMMARY OF THE PARAMETERS OF THE AVERAGE MONTHLY RAINFALL FOR BALTIMORE AIRPORT GAGE 1948-1975

	DURATION hr.	VOLUME cm	INTENSITY cm/hr.	P_c cm/hr.	T_p hr.	AVERAGE NUMBER STORMS
January	9.12	7.9	9	1.7	3.37	8.14
February	8.96	9.8	1.1	2.4	3.89	7.63
March	7.55	9.9	1.3	2.3	3.31	8.78
April	6.40	7.8	1.3	2.6	2.97	10.24
May	4.93	8.8	1.8	3.6	2.74	10.52
June	3.52	9.5	2.7	4.8	1.71	9.65
July	3.32	0.8	3.2	6.1	1.79	9.11
August	4.18	2.3	2.9	5.8	1.98	9.48
September	5.39	10.7	2.0	3.6	2.63	7.29
October	7.62	11.1	1.5	3.2	3.20	6.60
November	8.58	10.9	1.3	3.1	3.60	6.78
December	11.12	12.3	1.1	3.8	3.85	7.46

FIGURE 14
AVERAGE RAINFALL PROFILE

JUNE 1948-1975



For each month, the model computes the runoff for the average storm for that month. The pollutant load is computed for that storm. Total monthly pollutant loads are computed by multiplying the load for the average storm by the average number of storms for the month.

While the ECOsystem ECHOS model was designed to utilize the time history of runoff, the anticipated RPC data relating pollutant load to time history of discharge was not available. The RPC indicated that the relationships it had derived for pollutant load to total runoff would provide the information desired on total annual pollutant loads. Subsequent improvements with the time history of runoff should improve upon the results. Appendix A gives a detailed listing of the ECHOS model with examples of the data input required.

6.3 Calibration of the Runoff Portion of the ECHOS Model

Calibration of the ECHOS model requires the measurement, derivation, or estimation of the hydrologic parameters which permit it to most accurately reflect the actual behavior of the basin. Most of the parameters required are relatively easy to determine. Average slope, area, flow lengths, and channel dimensions are readily available from sources such as USGS topographic maps. Other parameters, however, are not so well understood or documented. It is particularly difficult, for example, to have accurate knowledge of movement of sub-surface water or soil moisture content just prior to a rainfall event.

These parameters were estimated for the Magothy River Watershed using the rainfall and runoff records described in the previous section. The calibration was made for the Cape St. Clair sub-basin and the results extrapolated to the remainder of the watershed. A map of Cape St. Clair is shown in Figure 15.

Manning's "n" was estimated directly from this LANDSAT classification by using the relationships given in Table IX. Preliminary estimates of soil moisture parameters were made from the SCS soil survey for Anne Arundel County, Maryland and used the SCS land cover relationships. These included final (saturated) infiltration rate, soil moisture capacity and percolation rate. Antecedent soil moisture was estimated using the following relationship adapted from the US Weather Bureau:

$$ASM_{(n)} = P_{(n)} + .9ASM_{(n-1)}$$

where:

ASM_n = Antecedent moisture on day (n)

P_n = Precipitation on day (n)

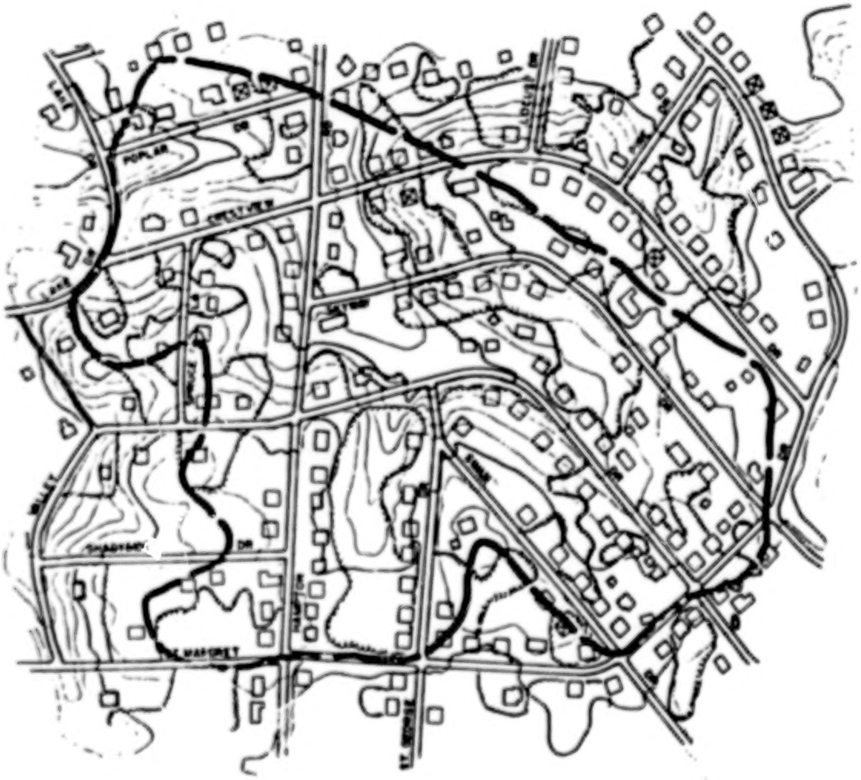
$ASM_{(n-1)}$ = Antecedent moisture on day (n-1)

The initial value of the antecedent soil moisture (ASM) was assumed to be zero immediately after the longest dry period occurring from ten to twenty days prior to the day of the test event. Values of ASM were then computed for each day, up to the day of the test event. The final value was used as an initial estimator for the ASM for each event.

Once the initial value of all parameters required by the mode was determined, a series of calibration runs were made for the March, April, and July events. Discrepancies in the runoff rate recorded for the February event precluded its use for calibration.

FIGURE 15

CAPE ST. CLAIR - SUBBASIN


POPLAR
DR
CRESTVIEW
LAKE
VALLEY
SHADYSIDE
DR
ST. MARGARET
ST. GEORGE

SOURCE: BALTIMORE REGIONAL PLANNING COUNCIL

TABLE IX

MANNING'S ROUGHNESS COEFFICIENT FOR OVERLAND FLOW FOR VARIOUS SURFACE TYPES

WATERSHED SURFACE	MANNING'S "N"
Smooth Asphalt	0.013
Concrete (Trowel Finish)	0.013
Rough Asphalt	0.016
Concrete (Unfinished)	0.017
Smooth Earth (Bare)	0.018
Firm Gravel	0.020
Cemented Rubble Masonry	0.025
Pasture (Short Grass)	0.030
Pasture (High Grass)	0.035
Cultivated Area (Row Crops)	0.035
Cultivated Area (Field Crops)	0.040
Scattered Brush, Heavy Weeds	0.045
Light Brush and Trees (Winter)	0.050
Light Brush and Trees (Summer)	0.060
Dense Brush (Winter)	0.070
Dense Brush (Summer)	0.100
Heavy Timber	0.100
Idle Land	0.030
Grass Land	0.032

Results of the first runs showed that the initial percolation rates chosen were too large, causing the upper soil layer to drain too quickly. This parameter was adjusted and subsequent runs made until a satisfactory fit was realized. An example of the goodness-of-fit of the technique is shown in Figure 16 for the 25 July 1977 event.

At this stage in the calibration, all but one of the parameters were fixed. Final calibrations were made by adjustment of antecedent soil moisture. It was anticipated that some refinement might be necessary to compensate for the fact that average, rather than peak rainfall data were to be used as inputs to the model. The average rain intensity derived from the statistics of the Airport gage were generally lower than the three test events at Cape St. Clair.

In order to correctly adjust the antecedent soil moisture, it was necessary to compute the fraction of runoff expected from rainfall for each month. Values for the months of the test events could be calculated directly as shown in Table X. Alternately and for the general case of limited data, the SCS curve numbers procedure using LANDSAT derived land cover was used to test the validity for ungaged basins. For the remaining months, the average value of 1.78 was used. This fraction was applied to the average rainfall volumes by month to compute expected monthly runoff. Figure 17 shows the computed monthly runoff volume as a % of the rainfall for a typical sub-basin, Dividing Creek.

The final calibration runs were made by adjusting antecedent moisture. Dividing Creek was used due to its homogeneous composition, relatively large size, and monostream configuration.

FIGURE 16

RESULTS OF THE CALIBRATION RUN FOR CAPE ST. CLAIR WATERSHED FOR THE

25 JULY 77 EVENT

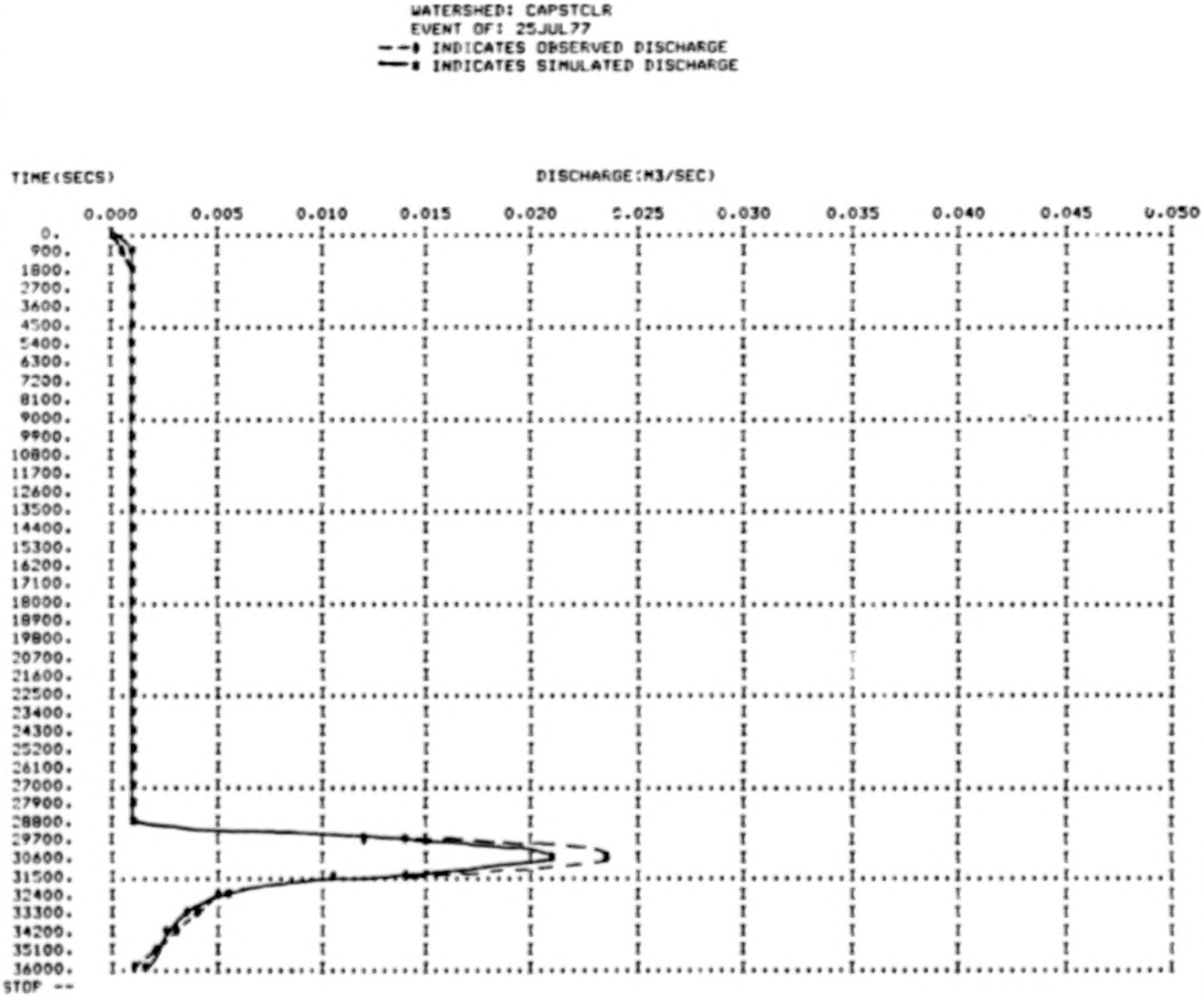


TABLE X

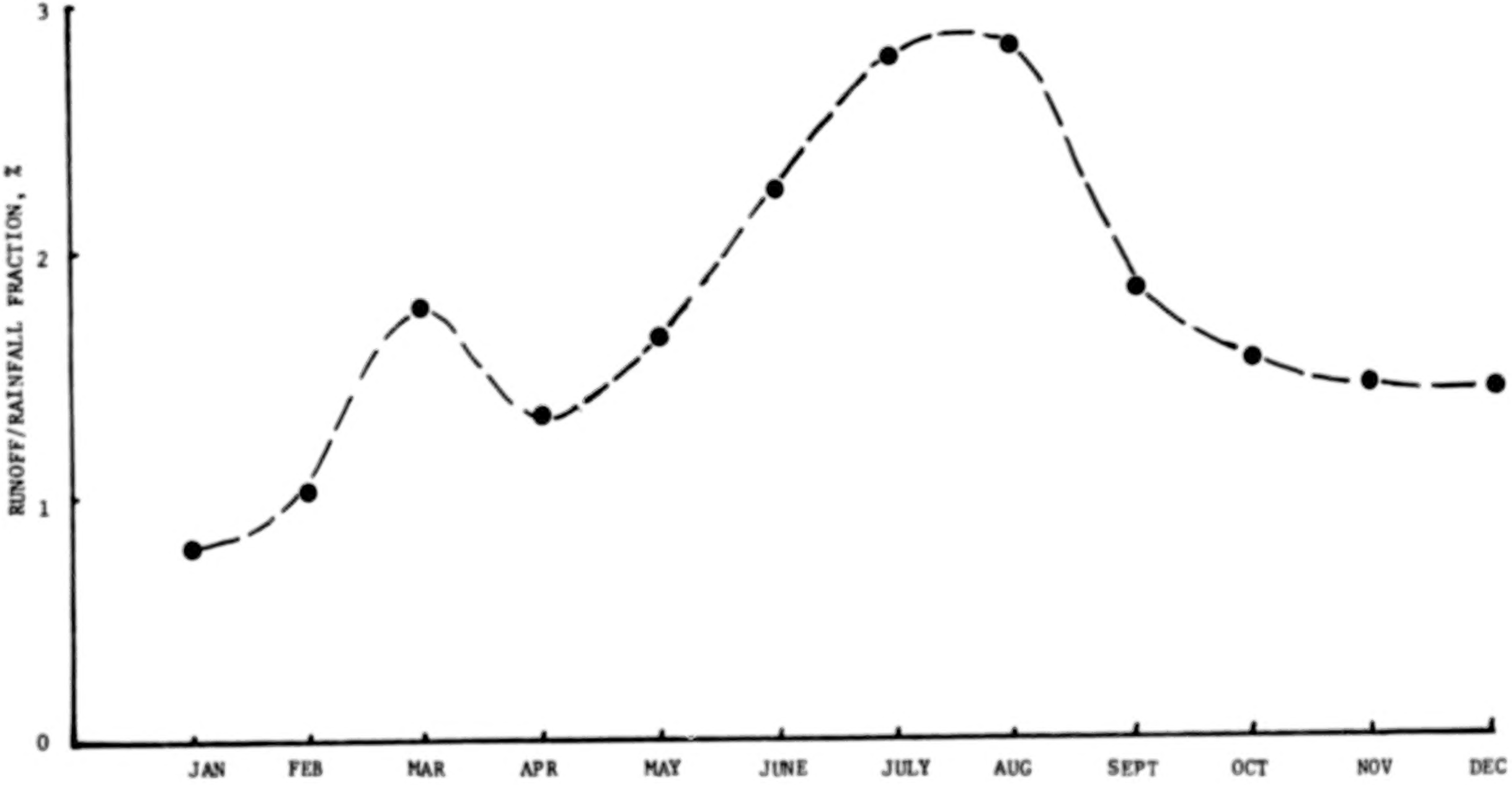
RUNOFF AS A % OF RAINFALL FOR THE CAPE ST. CLAIR SUBBASIN CALIBRATION EVENTS

	RAINFALL VOLUME (cubic meters)	DISCHARGE VOLUME (cubic meters)	RUNOFF AS A % OF RAINFALL
FEB	1982	20.0	1.0%
MAR	1353.8	32.65	2.0%
APR	5560	72.3	1.3%
JULY	3771.2	87.3	2.8%

AVERAGE PERCENT DISCHARGE = 1.78%

FIGURE 17

DIVIDING CREEK SUB-BASIN PERCENT OF RAINFALL BECOMING DIRECT RUNOFF



Three runs were made for each month at different values of antecedent moisture. The volume of runoff was recorded and plotted on a graph of discharge versus antecedent moisture. Interpolated values of ASM at zero error were then read directly from the graph. The results of repeating this process for each month are given in Figure 18. This curve is indicative of rational hydrologic behavior. Lower values of soil moisture are evidenced in months with higher evapotranspiration and solar radiation and vice-versa. The antecedent moisture figures derived for Dividing Creek were assumed to hold for all other subbasins.

6.4 Derivation of Pollution Loading Factors for Magothy River Basin

Non-point source pollutant estimation from land cover classification involves the use of empirical loading factors which relate pollutant loads to the land use classes, generally:

$$PL_j = \sum_{j=1}^{m} \sum_{i=1}^{n} (LU_i \times LF_{ij})$$

where:

PL_j = Pollutant load, volume/time

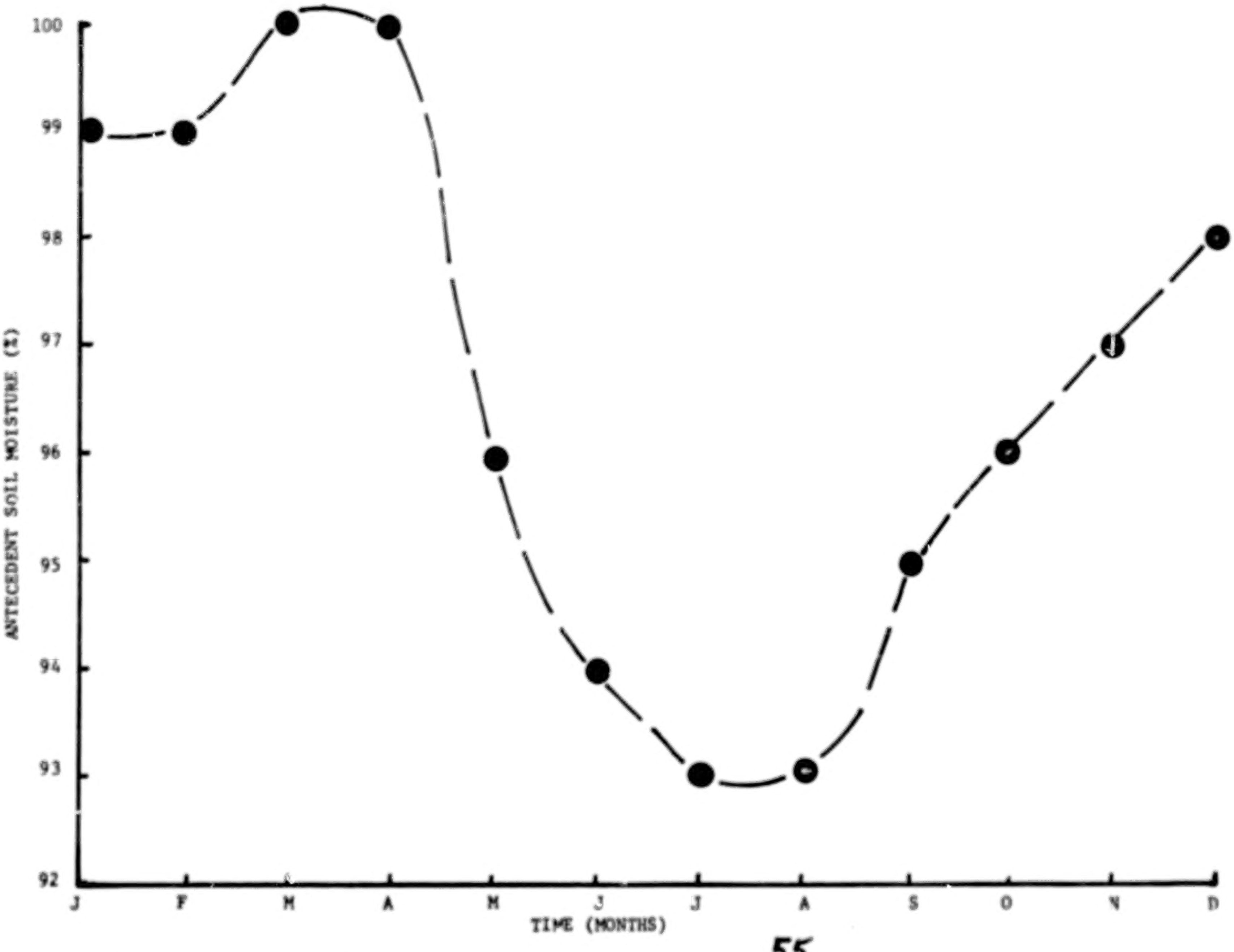
LU_i = Area of land use type i, area

LF_{ij} = Loading factor for land use type i and pollutant type j, volume/unit area/time

The available data supplied by the RPC, indicated that the estimation of pollutant load from land cover measured by LANDSAT was the preferable technique. Pollution assessment from streamflow, precipitation,

FIGURE 18

MONTHLY VALUES OF ANTECEDENT SOIL MOISTURE SELECTED FOR THE MAGOTHY SIMULATION



and sediment load are generally more applicable to very large areas and do not adequately reflect the response characteristics of small basins. The general form of the sediment-pollutant coefficients would not account for loading differences among the smaller Magothy sub-basins. The use of land class - pollutant loading factors directly uses the surficial and temporal characteristic of the watershed and is therefore directly amenable to remote sensing analysis.

The applicability of loading factors derived for one geographic area to another locale is not certain. It is far preferrable to use loading factors developed in the region under study. The availability of extensive water quality sampling at the RPC provided ECOsystems with the necessary data.

With the assistance and at the direction of the RPC, two such sets of loading coefficients were investigated. One was developed for watersheds in North Carolina and the other by the Washington Council of Governments for Maryland and Virginia basins. The data for the pollutants of interest the RPC are shown in Tables XI and XII. These data sets were judged suitable for the Magothy by the RPC because of their geographic proximity and because they showed a reasonable numerical consistency for the individual pollutants.

The loading factors were stored on computer disk files to be read into the ECHOS model. After the cumulative monthly discharge was computed for a sub-basin, the program calculates a weighted average pollutant concentration based upon the fraction of the sub-basin in each land use class. These factors are then multiplied by the discharge to yield total pollutant loading. This procedure is repeated for each

TABLE XI

POLLUTANT LOADING FACTORS - WASH/COG

LAND USE	SUSPENDED SOLIDS (mg/1)	BOD (mg/1)	COD (mg/1)	TOTAL KJELDAHL NITROGEN (mg/1)	TOTAL NITROGEN (mg/1)	TOTAL PHOSPHOROUS (mg/1)
Shopping Ctr.	74	No Data	54.66	1.81	2.43	0.20
Strip Commercial	98		111.53	1.33	1.76	0.27
High Rise Residential	34		96.28	0.87	1.20	0.22
Townhouse/ Garden Apts.	115		73.46	1.12	1.49	0.29
Med. Density Residential	42		95.88	1.94	2.42	0.38
Large Lot Residential	142		115.15	2.76	3.64	0.35
Construction	763		89.35	1.61	1.76	0.26
Forest	No Data		72.40	1.28	1.30	0.12
Conventional Till Agri.	1681		853.4	8.90	13.42	3.18
Minimum Till Agri.	133		86.24	1.93	3.52	1.14
Pasture	544		549.00	4.97	5.16	1.06

TABLE XII

POLLUTANT LOADING FACTORS - RFC - TRIANGLE 5

LAND USE	% IMPERVIOUS AREA	SUSPENDED SOLIDS CONCENTRATION (mg/l)	BOD CONCENTRATION (mg/l)	COD CONCENTRATION (mg/l)	TOTAL KJELDAHL NITROGEN CONCENTRATION (mg/l)	TOTAL PHOSPHOROUS CONCENTRATION (mg/l)
Rural	4	167	7.0	38.2	0.71	0.41
LAC	12	239	7.6	61.1	1.03	0.47
LAR	16	293	7.7	76.1	2.32	0.49
HAR	32	751	12.2	140.6	2.34	0.68
HAC	35	633	13.2	172.8	2.22	0.60
CBD	80	179	15.3	178.2	2.97	0.46

LAC = Low Activity Commercial
LAR = Low Activity Residential
HAR = High Activity Residential
HAC = High Activity Commercial
CBD = Central Business District

month. At the end of the year's simulation, an annual total is calculated.

6.5 Simulation of Magothy River with ECHOS Model

The ECHOS model approximates the natural basins of irregular shape as areally equivalent rectilinear areas having areally averaged hydrologic parameters derived from existing data. These segments are tributary to channel segments with assumed rectangular cross sections and uniform geometric and hydrologic characteristics all along its length. The numbers of blocks and stream segments required for simulation is dictated by the size and geometry of the actual basin.

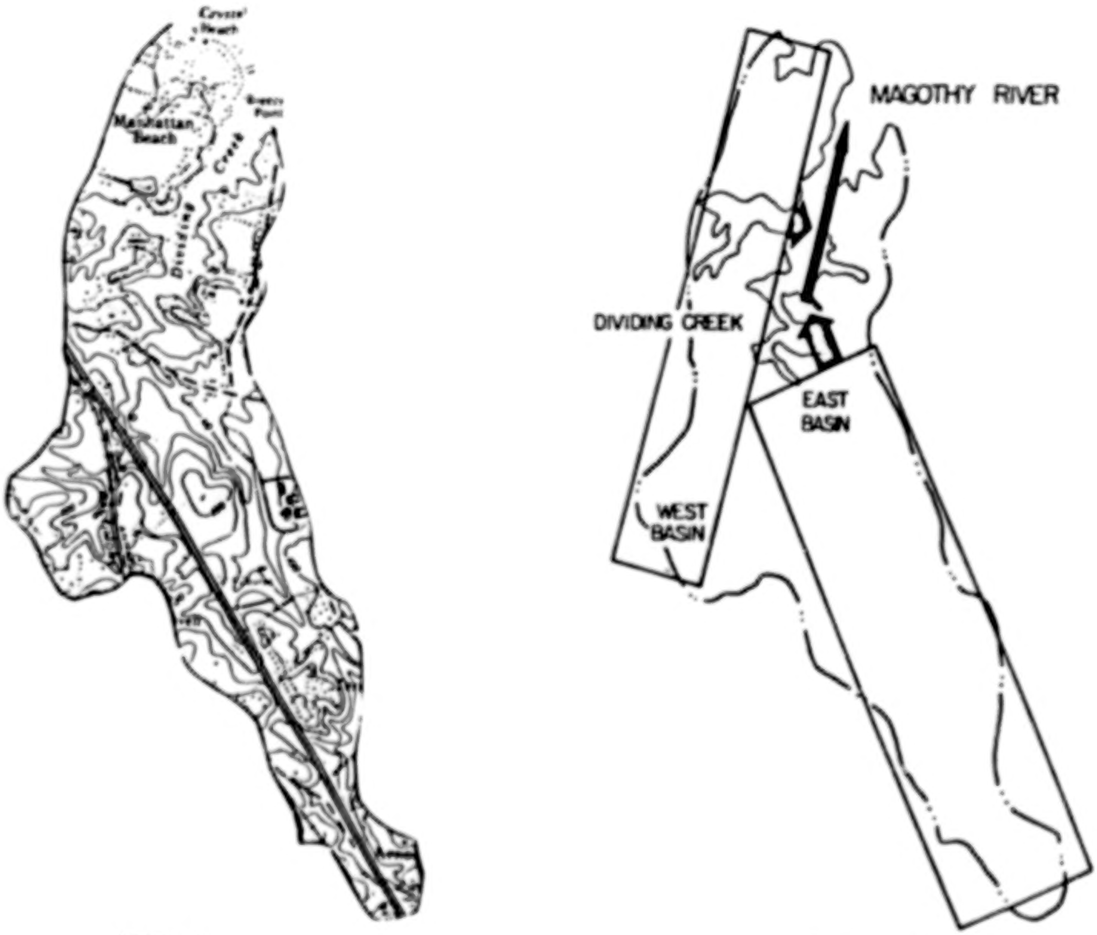
Figure 19 shows the Dividing Creek sub-basin. The sub-basin is composed of one main stream separating two half basins. Both half basins generally flow into Dividing Creek rather than into the Magothy River. The sub-basin was approximated by two blocks and a single stream segment. Figure 20 shows the computer approximation for the Little Magothy River sub-basin. Because a significant fraction off this sub-basin drains directly into the main channel of the Magothy River, it was approximated by three blocks as shown in the figure.

Average hydrologic, soils and physiographic properties were assigned to each sub-basin as shown in Table XIII. The computer program reads in the parameters for a single sub-basin, the basin structure, monthly rainfall profiles, and the loading factors and then performs overland flow and channel routing calculations.

A series of twelve monthly simulations were made for each of the sub-basins. The results from each run were converted to pollutant

FIGURE 19

COMPUTER REPRESENTATION OF THE DIVIDING CREEK WATERSHED

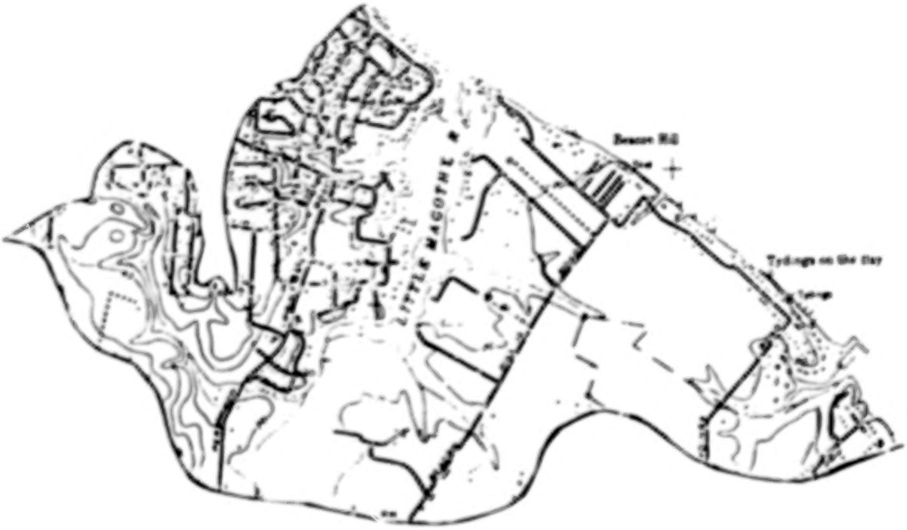

Manhattan Beach
Dividing Creek
MAGOTHY RIVER
DIVIDING CREEK
EAST BASIN
WEST BASIN

ACTUAL

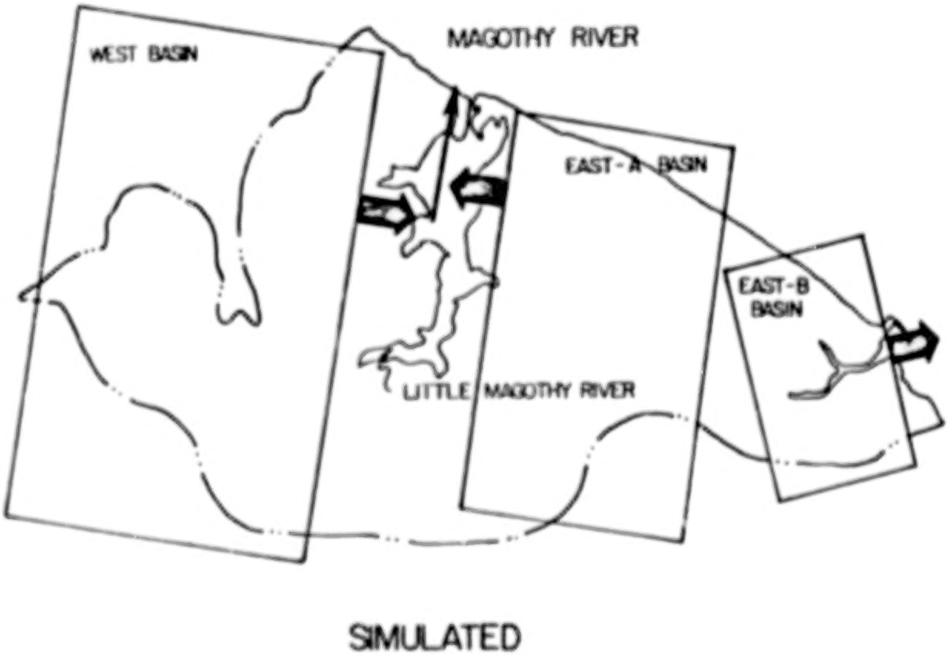
SIMULATED

FIGURE 20

COMPUTER REPRESENTATION OF THE LITTLE MAGOTHY RIVER WATERSHED


LITTLE MAGOTHY R.
Tydings on the Bay

ACTUAL


WEST BASIN
MAGOTHY RIVER
EAST-A BASIN
EAST-B BASIN
LITTLE MAGOTHY RIVER

SIMULATED

TABLE XIII

MAGOTHY RIVER BASIN - MODEL ECHOS MODEL DATA INPUT

SUBBASIN #		AREA (m^2)	SLOPE (%)	OVERLAND FLOW AVERAGE LENGTH (m)	CHANNEL LENGTH (m)	WIDTH (m)	MANNINGS "N"	SOIL CAPACITY (m)	INFILTRATION I_f m/hr	PERCOLATION m/hr
1	W	494423.79	.074	328.08	*	507	.072	.023	.039	.001
	E	483271.37	.037	272.07		1776	.065	.064	.037	.001
2		6744909.78	.017	540.14	*	12487	.066	.038	.065	.001
3	W	2628252.78	.038	486.12	2743.90	5407	.076	.039	.054	.001
	E	2226765.79	.017	606.15		3674	.064	.055	.069	.001
4	W	825278.81	.015	544.14	2743.90	1517	.083	.034	.059	.001
	E	1799256.50	.039	640.16		2811	.098	.031	.049	.001
5	W	3936802.95	.021	720.18	3963.41	5466	.071	.038	.121	.001
	E	3935687.71	.008	558.14		7051	.078	.043	.113	.001
6	W	11192803.06	.025	1104.28	7621.95	10136	.070	.043	.140	.001
	E	12695419.07	.021	849.81		14939	.064	.044	.130	.001
7	W	1286245.35	.027	449.75	3048.78	2860	.078	.048	.116	.001
	E	1037174.72	.028	426.83		2430	.093	.053	.138	.001
8	W	4078066.89	.025	942.24	6097.56	4328	.077	.043	.121	.001
	E	2888475.82	.033	576.14		5014	.068	.047	.082	.001
9	W	2200743.48	.017	800.20	2743.90	2750	.052	.041	.123	.001
	E	817843.86	.034	360.09		2271	.054	.052	.082	.002
10	W	1148698.88	.029	576.15	2134.15	1994	.084	.033	.040	.001
	E	360594.79	.055	304.08		1186	.042	.038	.068	.001
11	W	2713754.53	.037	594.15	3963.41	4568	.085	.044	.050	.001
	E	1237918.21	.033	504.13		2456	.056	.050	.045	.001
12	W	1858736.05	.036	117.30	4115.85	15846	.057	.029	.047	.001
	E	2788104.08	.049	534.13		5220	.061	.046	.061	.001
13	W	2174721.18	.042	600.15	2743.90	3624	.073	.055	.122	.001
	E_A	2068439.00	.069	416.10		4971	.081	.040	.056	.001
	E_B	1360223.47	.032	640.16	*	2108	.039	.030	.046	.001
14	W	3572490.69	.034	792.20	3048.78	4510	.073	.051	.057	.001
	E	2468401.47	.051	492.12		5016	.042	.039	.077	.001
15	W	2068439.00	.026	368.09	3963.41	5619	.067	.043	.076	.001
	E_A	2117153.34	.013	688.17		3077	.047	.059	.109	.001
	E_B	1199095.07	.006	496.12	*	2417	.082	.061	.090	.001

*Sub-basin drains directly into Magothy River loads using the two transfer tables supplied by the RPC. Monthly totals were computed for each sub-basin by multiplying the simulation values by the average number of storms for that month and an aggregate yearly total was determined. The simulation of the Magothy was performed for each of the 17 sub-basins shown delineated in Figure 21.

6.6 Non-Point Source Pollutant Loads for the Magothy for 1977

Average monthly runoff was simulated for the 1977 calendar year for the Magothy Basin in Anne Arundel County, Maryland.

Pollutant concentration coefficients derived from empirical data and LANDSAT derived surface cover were used to convert monthly runoff to monthly pollutant load for the 17 sub-basins comprising the Magothy Basin.

Monthly and annual pollutant loads were estimated including total suspended solids, BOD, COD, total Kjedahl nitrogen, total nitrogen and total phosphorous using average loading coefficients supplied by the RPC.

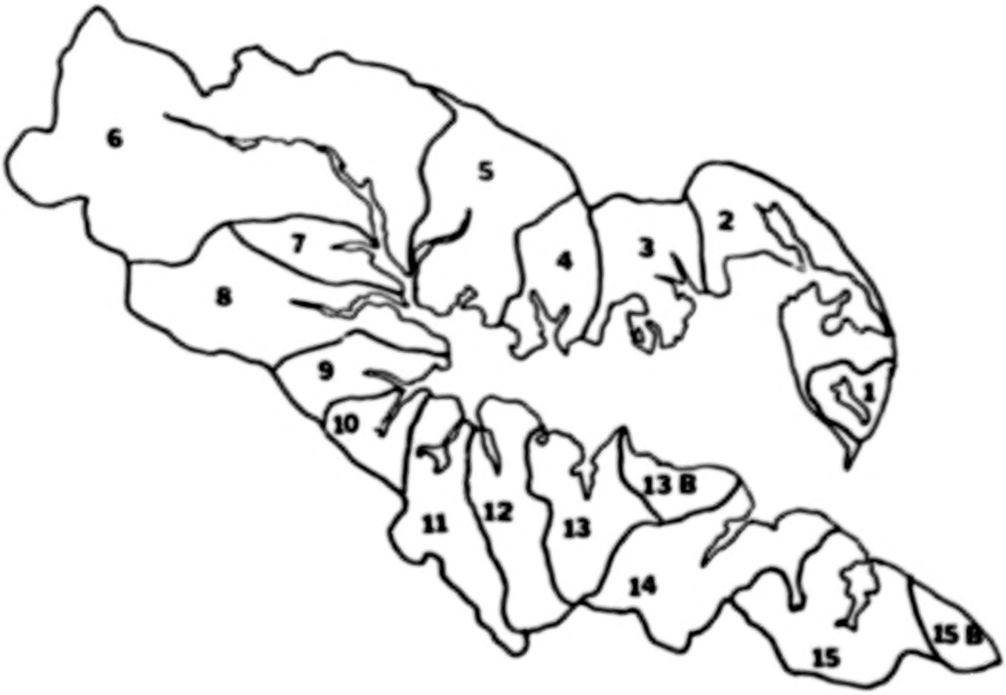
Individual storm load estimates compared very closely to the limited stream sampling data supplied by the RPC.

Table XIV summarizes the % of annual pollutant loads estimated by the ECHOS model for the Magothy Basin by sub-basin. The results of the simulation indicates that the storm load contribution for the pollutants in metric tons/year are given in Table XV.

Table XVI presents the annual average unit pollutant loads for the sub-basins and represents the pollutant loads adjusted to compensate for the area variation between the sub-basins. When the unit pollutant loads for each pollutant component is compared to the unit volume of

FIGURE 21

MAGOTHY RIVER SUB-BASINS



SUBBASIN #I	SUBBASIN NAME	AREA (hectares)	% AREA	SUBBASIN #II	SUBBASIN NAME	AREA (hectares)	% AREA
1	Otter Pond	116.2	1.4	10	Cypress Ck.	151.0	18
2	Cornfield Ck.	669.2	7.8	11	Dividing Ck.	395.0	4.6
3	Grays Ck.	485.6	5.6	12	Mill Ck.	464.8	5.4
4	Blackhole Ck.	262.6	3.1	13	Forked Ck.	435.0	5.1
5	Cockey Ck.	757.4	8.8	13B	Bayberry	122.6	1.4
6	Lake Waterford	2370.1	27.6	14	Deep Ck.	604.1	6.9
7	Old Man Ck.	232.3	2.7	15	Little Magothy River	426.3	4.9
8	Cattail Ck.	497.0	8.1	15B	Tydings	108.1	1.3
9	Cape Arthur	302.0	3.5				

TABLE XIV

RPC - TRIANGLE J DATA

AREAS		% OF TOTAL POLLUTANT LOAD					
	TSS	BOD	COD	TKN	TN	TP	AREA
Otter Pond	4.1	4.4	4.1	3.9	-	4.3	1.3
Cornfield	5.7	5.7	5.8	6.0	-	5.6	7.8
Grays Creek	5.0	4.9	5.0	5.4	-	5.0	5.7
Blackhole Creek	0.9	1.1	0.9	0.6	-	1.2	3.0
Cockeys Creek	4.5	4.6	4.4	4.3	-	4.3	8.8
Lake Waterford	23.1	23.0	22.7	21.9	-	23.0	27.6
Old Man Creek	1.3	1.4	1.2	1.1	-	1.2	2.7
Cattail Creek	1.2	1.2	1.2	1.1	-	1.2	8.1
Cape Arthur	2.2	2.0	2.3	2.4	-	1.9	3.5
Cypress Creek	3.8	4.0	3.8	3.6	-	3.7	1.8
Dividing Creek	1.7	2.0	1.6	1.3	-	1.9	4.6
Mill Creek	7.3	7.3	7.3	7.5	-	7.5	5.4
Forked Creek	8.5	9.2	8.3	7.5	-	9.3	5.1
Bayberry	6.6	5.6	6.9	8.2	-	5.6	7.0
Deep Creek	19.0	18.3	19.4	20.4	-	18.6	5.0
Little Magothy River	2.5	2.5	2.4	2.4	-	2.5	1.4
Tydings	2.7	2.9	2.7	2.6	-	3.1	1.2
MT/yr.	91	3.1	22.1	0.54	-	0.19	
Kg/ha.	782.8	26.5	190.5	4.67	-	1.61	

TABLE XIV (cont'd)

WASHINGTON - COG DATA

AREAS	% OF TOTAL POLLUTANT LOAD						
	TSS	BOD	COD	TKN	TN	TP	AREA
Otter Pond	1.3	-	2.7	3.4	3.3	2.3	1.3
Cornfield	5.3	-	5.9	5.9	5.8	5.5	7.8
Grays Creek	2.4	-	3.2	4.2	4.2	3.1	5.7
Blackhole Creek	.3	-	.6	.75	.63	.78	3.0
Cockey Creek	3.2	-	4.1	4.2	4.1	3.1	8.8
Lake Waterford	34.2	-	25.4	24.3	25.6	27.3	27.6
Old Man Creek	.36	-	.8	1.0	1.0	.8	2.7
Cattail Creek	.75	-	1.0	1.1	1.05	.8	8.1
Cape Arthur	1.37	-	1.4	1.9	1.9	1.6	3.5
Cypress Creek	1.49	-	2.5	3.0	3.05	2.3	1.8
Dividing Creek	1.05	-	1.8	1.6	1.5	1.6	4.6
Mill Creek	9.8	-	10.0	8.5	8.2	8.1	5.4
Forked Creek	6.9	-	9.2	8.5	7.9	7.0	5.1
Bayberry	8.2	-	7.0	7.2	7.5	7.0	7.0
Deep Creek	16.9	-	17.9	18.6	18.7	16.0	5.0
Little Magothy River	5.7	-	4.6	3.6	3.6	4.7	1.4
Tydings	.9	-	1.8	2.2	2.1	1.6	1.2
MT/yr	447.7	-	498.8	8.02	9.50	1.28	
Kg/ha.	52.1	-	58.0	0.93	1.11	0.15	

TABLE XV

ANNUAL POLLUTANT LOADS FOR THE MAGOTHY

(Metric Tons/year)

POLLUTANT	DATA SOURCE		
	RPC (TJ)	WASH-COG	AVERAGE
TSS	782.8	447.7	615.3
BOD	26.5	-	26.5*
COD	190.5	498.8	344.7
TKN	4.67	8.02	6.3
TN	-	9.5	9.5*
TP	1.61	1.28	1.4

---

*Not averaged.

TABLE XVI

AVERAGE ANNUAL POLLUTION LOADING (Kg/Ha) MAGOTHY RIVER BASIN

SUB-BASIN	TSS	BOD	COD	TKN	TN	TP	VOLUME DISCHARGE (m^3)	UNIT VOLUME (m^3/hec)
1. Otter Pond	164.82	9.88	91.51	1.95	2.66	0.43	19429.06	167.20
2. Cornfield	51.39	2.28	30.32	0.56	.82	0.12	23600.95	35.27
3. Grays Creek	50.97	1.68	26.34	0.60	.84	0.12	21236.03	43.73
4. Black Hole Creek	14.28	1.04	8.76	0.17	.22	0.04	4267.46	16.27
5. Cockey Creek	32.40	3.24	11.20	0.72	1.02	0.08	20444.90	26.99
6. Lake Waterford	70.54	2.58	35.83	0.63	1.02	0.15	105387.43	44.47
7. Old Man Creek	24.88	1.58	14.14	0.29	.40	0.07	6065.37	26.11
8. Cattail Creek	8.99	.92	5.20	0.10	.28	0.02	5088.14	7.30
9. Cape Arthur	38.54	1.74	18.82	0.43	.60	0.08	8563.79	28.36
10. Cypress Creek	121.31	6.96	65.89	1.37	1.90	0.30	17322.87	114.72
11. Dividing Creek	22.38	1.64	15.24	0.24	.68	0.06	8444.76	21.39
12. Mill Creek	108.81	4.16	68.52	1.11	1.68	0.24	31231.09	67.19
13. Forked Creek	76.09	5.64	71.09	1.18	1.72	0.28	41534.26	95.48
13B Bayberry	360.30	12.16	195.38	3.89	5.82	0.73	2375.25	193.78
14. Deep Creek	186.21	8.04	104.55	2.02	2.94	0.42	80810.68	133.77
15. Little Magothy River	52.21	1.56	32.33	0.47	.80	0.11	10953.92	25.70
15B Tydings	116.83	7.12	65.03	1.38	1.88	0.30	13371.38	123.70

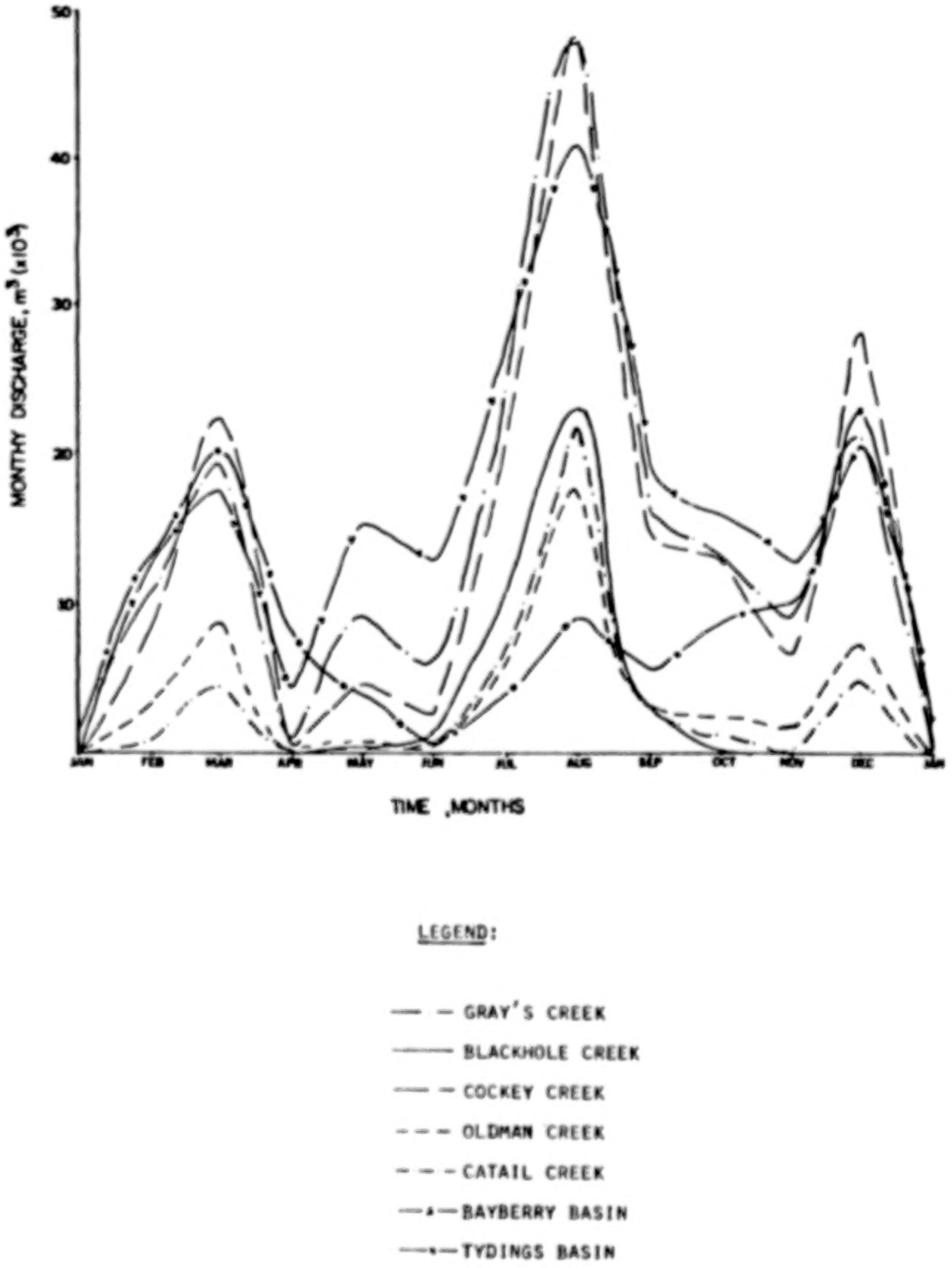
runoff, it is evident that the primary generator of high unit pollutant load response is the hydrologic response of the basin, i.e., the quantity of runoff per unit area. In each case, except Mill Creek, there is a direct correspondence between high unit pollutant load and high unit runoff.

The relatively high pollutant loads from Mill Creek can possibly be explained by the high fraction of pasture and commercial land use in Mill Creek which contribute high total suspended solids. Contrast the pollutant loads from Mill Creek with a unit volume of runoff of 67.2 m^3/ha. with that of the Tydings sub-basin which has equivalent pollutant loads but has almost double the (123.7 m^3/ha) unit volume of runoff.

Figure 22 displays the simulated monthly runoff for selected sub-basins of the Magothy. The relative magnitude of the curves are a direct result of the area variation since the rain was considered to be uniform over the total area. These curves all have a similar shape which is dictated by the assumption of uniform rainfall rate throughout the Magothy Basin. Minor differences, particularly for low values of runoff are a result of the variation of soils and infiltration between the sub-basins. For example, Blackhole Creek, which has approximately 3% of the total area, has significantly less runoff for the period January through June. Blackhole Creek is comprised of soils with higher percolation rates. Cockey Creek, which is approximately 9% of the total area, exhibits relatively high runoff for the whole year.

FIGURE 22

COMPUTED MONTHLY RUNOFF
FOR MAGOTHY RIVER SUB-BASINS WITH FLOW-DOMINATED
POLLUTANT LOADING



Since the pollutant load conversions are sensitive to the volume of runoff, the monthly runoff curves are a good indicator of the timing of the major pollutant contributions.

Figure 23 shows the relative monthly contribution of pollutants for the Dividing Creek sub-basin and is characteristic of all of the sub-basins. The large contribution for the period centered upon August is a direct consequence of the rain profiles characteristic of the post summer period. Table XVII presents the summary of the average monthly rainfall event profiles. The table shows that the March-May period is characterized by low intensity rains of relatively long duration and which have relative low unit volumes. This combination tends to produce low runoff and hence low pollutant loading contributions. The July-September period, in contrast, is characterized by relatively short, high intensity rain events which produce higher runoff and thereby contribute high pollutant loads. The shift of the peak period toward the winter months is probably due to the seasonal effect of evapotranspiration which peaks in July and rapidly decays toward December as shown in Figure 24.

Figures 25a through f show the annual unit pollutant load (kg/hectare) for the Magothy Basins for the pollutants considered. These figures are compared with similar ones for land use and runoff in Figures 26 to 29. It is noted that the values for pollutant loads are rationally explained for the most part by the values of unit runoff. High values of unit runoff yield high across-the-board pollutant loadings, and the reverse is true for low unit runoff values. In certain cases, however, pollutant loading is "driven" by land use rather

FIGURE 23

TIME PHASING OF POLLUTANT LOAD

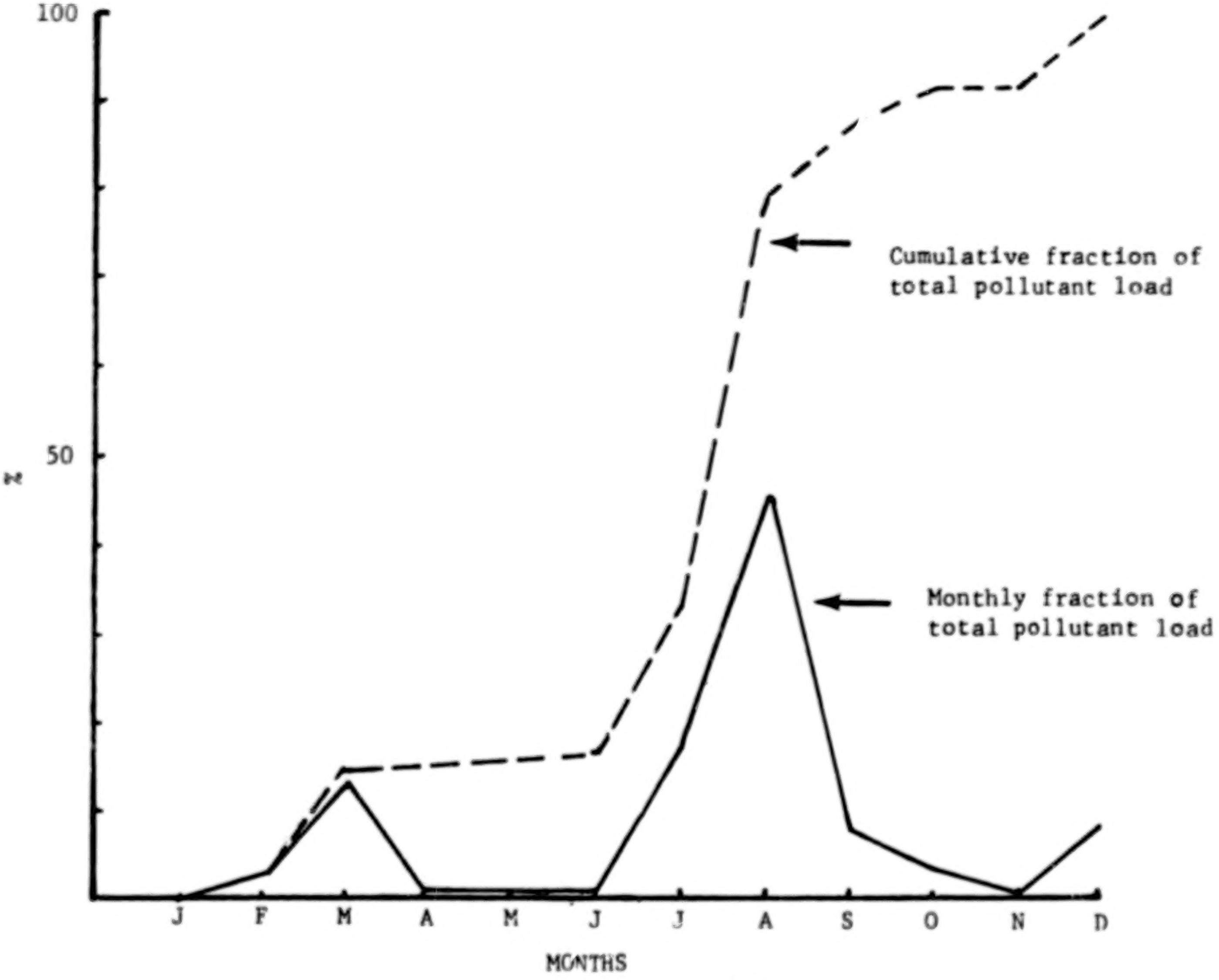


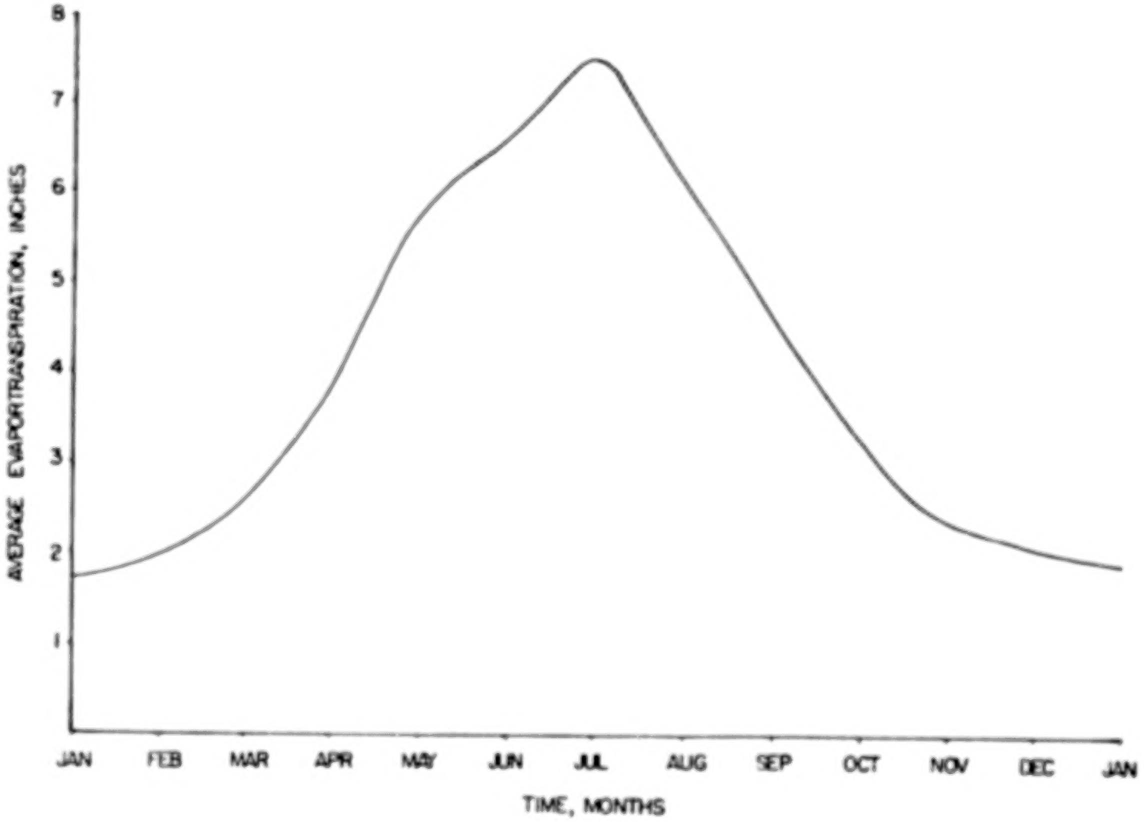
TABLE XVII

CHARACTERISTICS OF THE AVERAGE RAINFALL EVENT

	DURATION	UNIT VOLUME	INTENSITY mm/hr.
January	9.12	7.9	.9
February	8.96	9.8	1.1
March	7.55	9.9	1.3
April	6.40	7.8	1.3
May	4.93	8.8	1.8
June	3.52	9.5	2.7
July	3.32	10.8	3.2
August	4.18	12.3	2.9
September	5.39	10.7	2.0
October	7.62	11.1	1.5
November	8.38	10.9	1.3
December	10.91	12.3	1.1

FIGURE 24

20-YEAR AVERAGE MONTHLY EVAPORTRANSPIRATION AT BELTSVILLE, MD.



SOURCE: NATIONAL CLIMATIC CENTER, ASHVILLE, TENN.

UNIT POLLUTANT LOADING - MAGOTHY RIVER SUBBASINS

FIGURE 25a

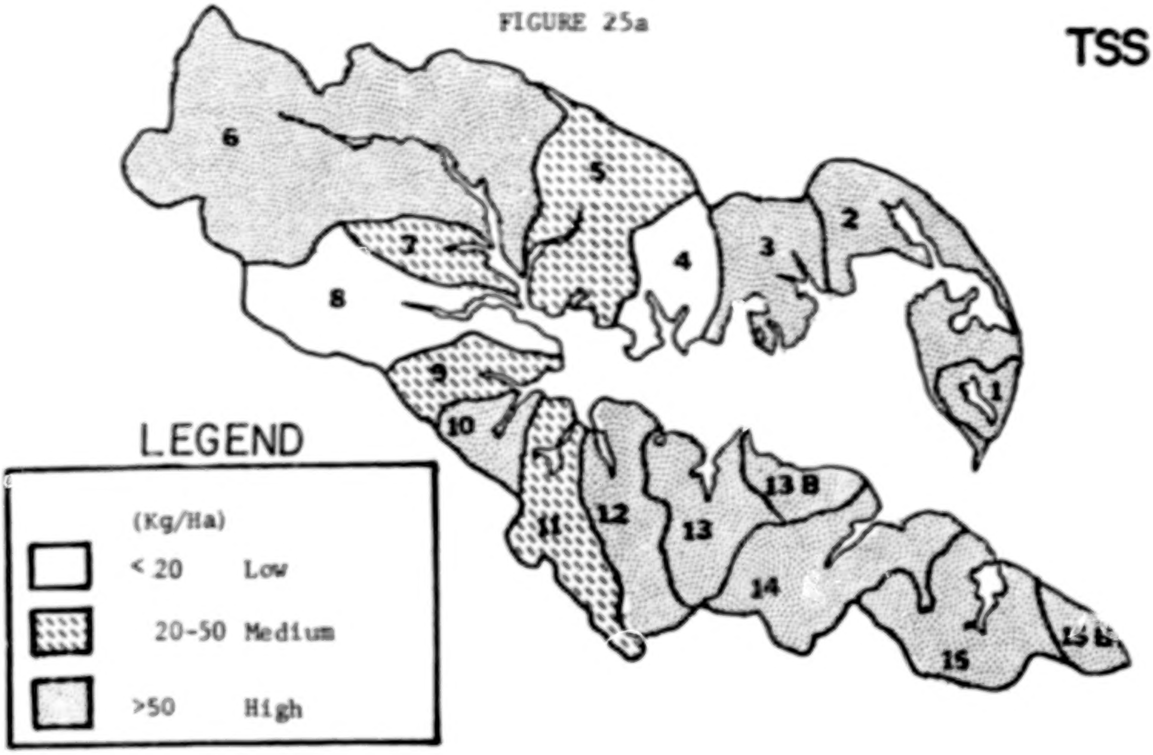
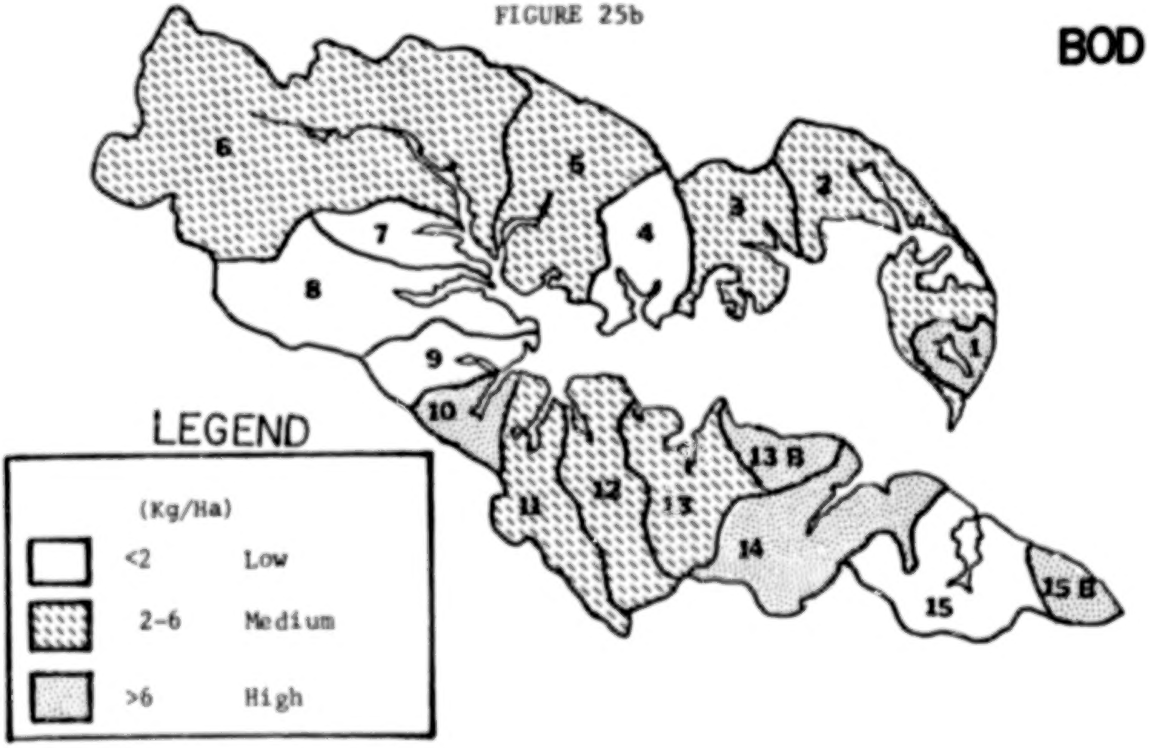

TSS
6
5
2
7
4
3
8
9
1
10
13 B
12
11
13
14
15
15 B
LEGEND
(Kg/Ha)
< 20 Low
20-50 Medium
>50 High

FIGURE 25b


BOD
6
5
2
3
7
4
8
1
9
10
13 B
12
11
13
14
15
15 B
LEGEND
(Kg/Ha)
<2 Low
2-6 Medium
>6 High

UNIT POLLUTANT LOADING - MAGOTHY RIVER SUBBASINS

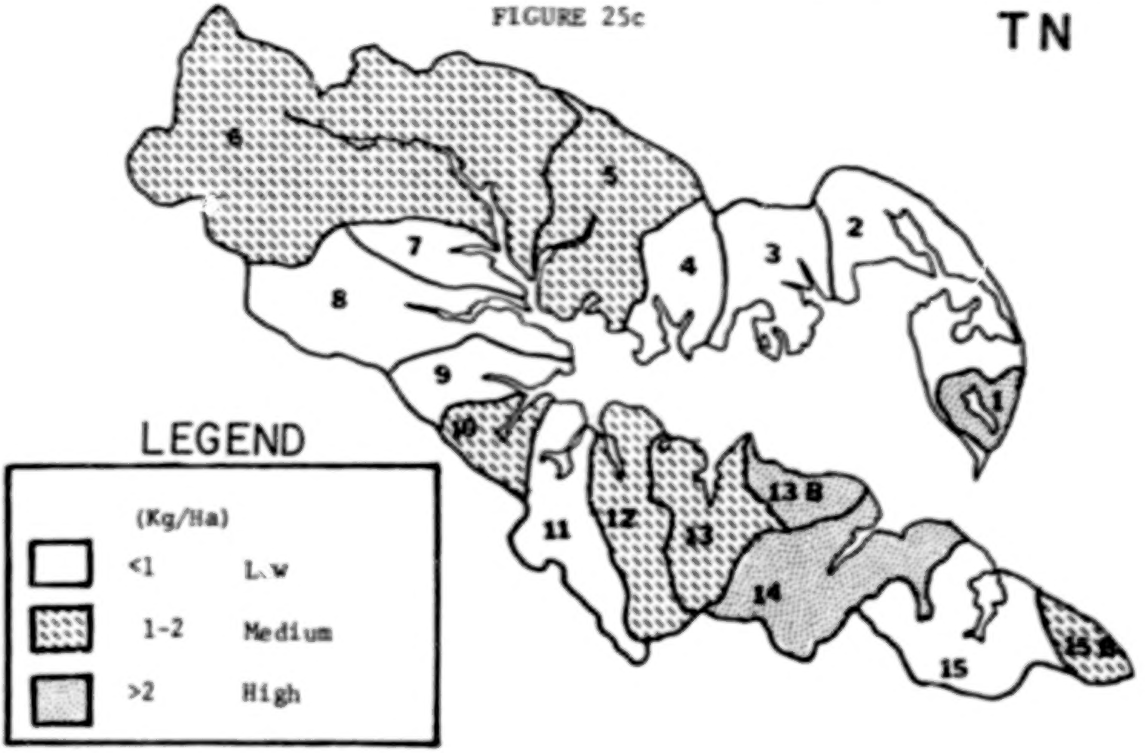


FIGURE 25c

TN
1
2
3
4
5
6
7
8
9
10
11
12
13
13 B
14
15
15 B
LEGEND
(Kg/Ha)
<1 Low
1-2 Medium
>2 High

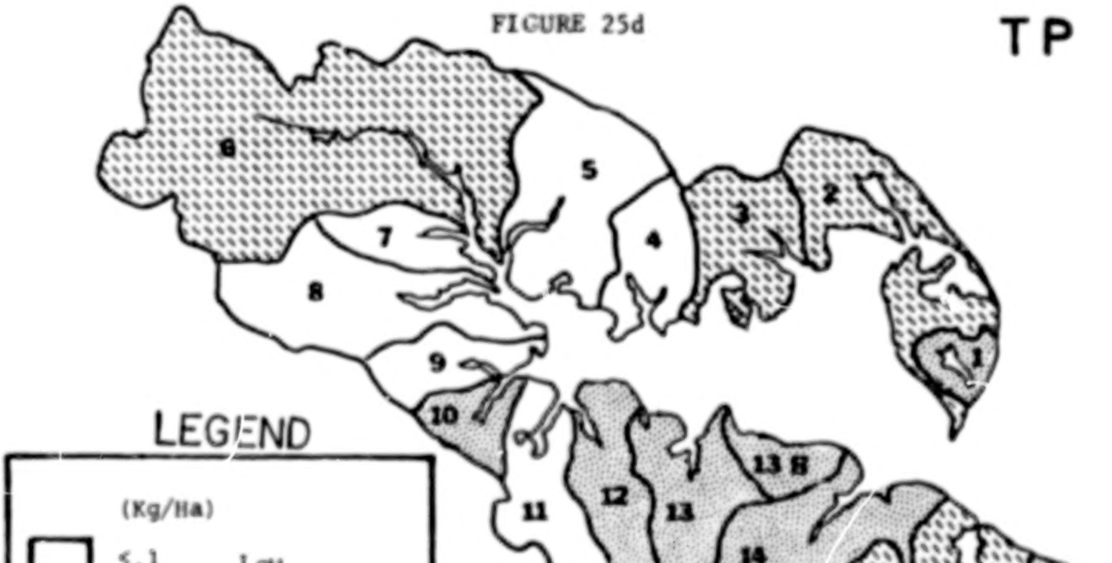


FIGURE 25d

TP
1
2
3
4
5
6
7
8
9
10
11
12
13
13 B
14
15
15 B
LEGEND
(Kg/Ha)
<.1 Low
.1-.2 Medium
>.2 High

UNIT POLLUTANT LOADING - MAGOTHY RIVER SUBBASINS

FIGURE 25e

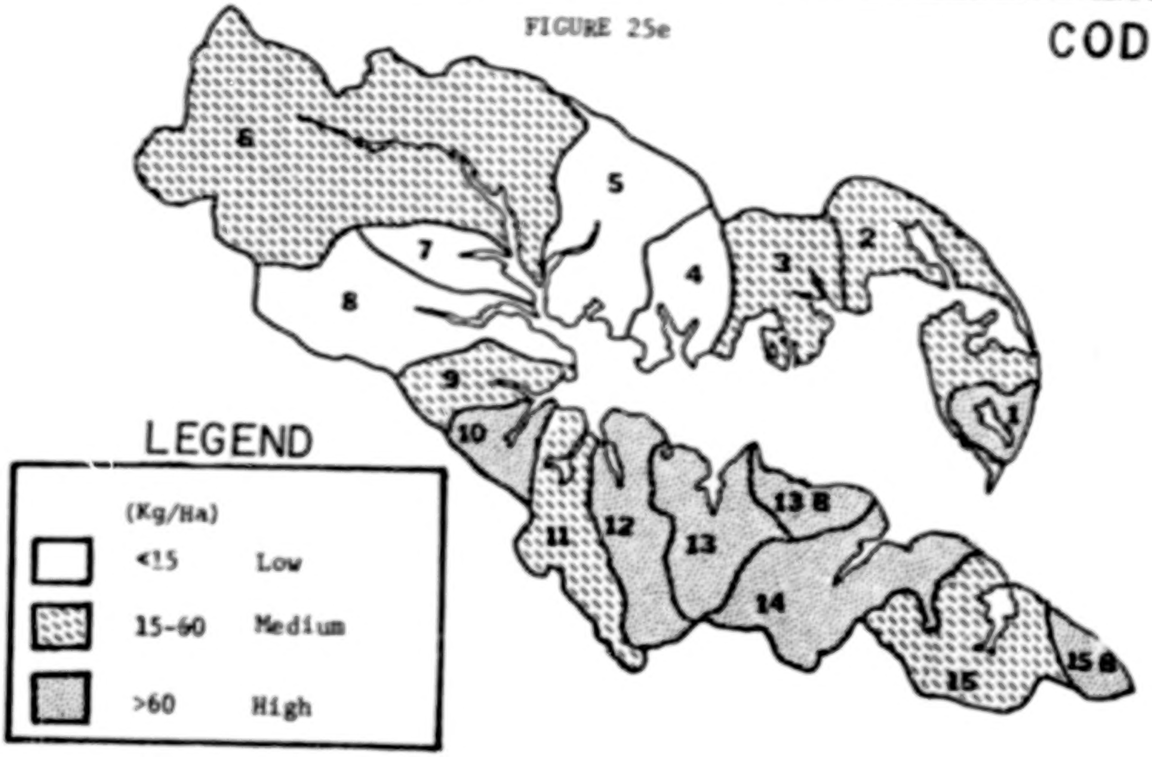

COD
6
5
4
3
2
1
7
8
9
10
11
12
13
13 B
14
15
15 B
LEGEND
(Kg/Ha)
<15 Low
15-60 Medium
>60 High

FIGURE 25f

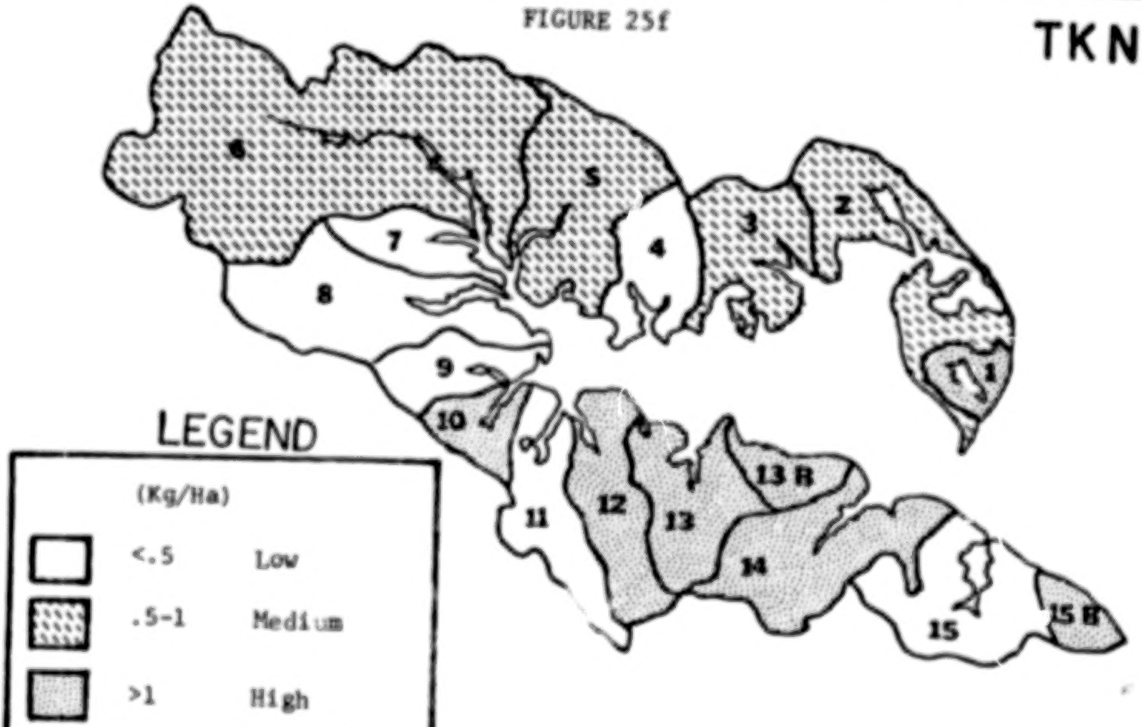

TKN
6
5
4
3
2
1
7
8
9
10
11
12
13
13 B
14
15
15 B
LEGEND
(Kg/Ha)
<.5 Low
.5-1 Medium
>1 High

FIGURE 26

PERCENT FOREST AREA - MAGOTHY RIVER SUBBASINS

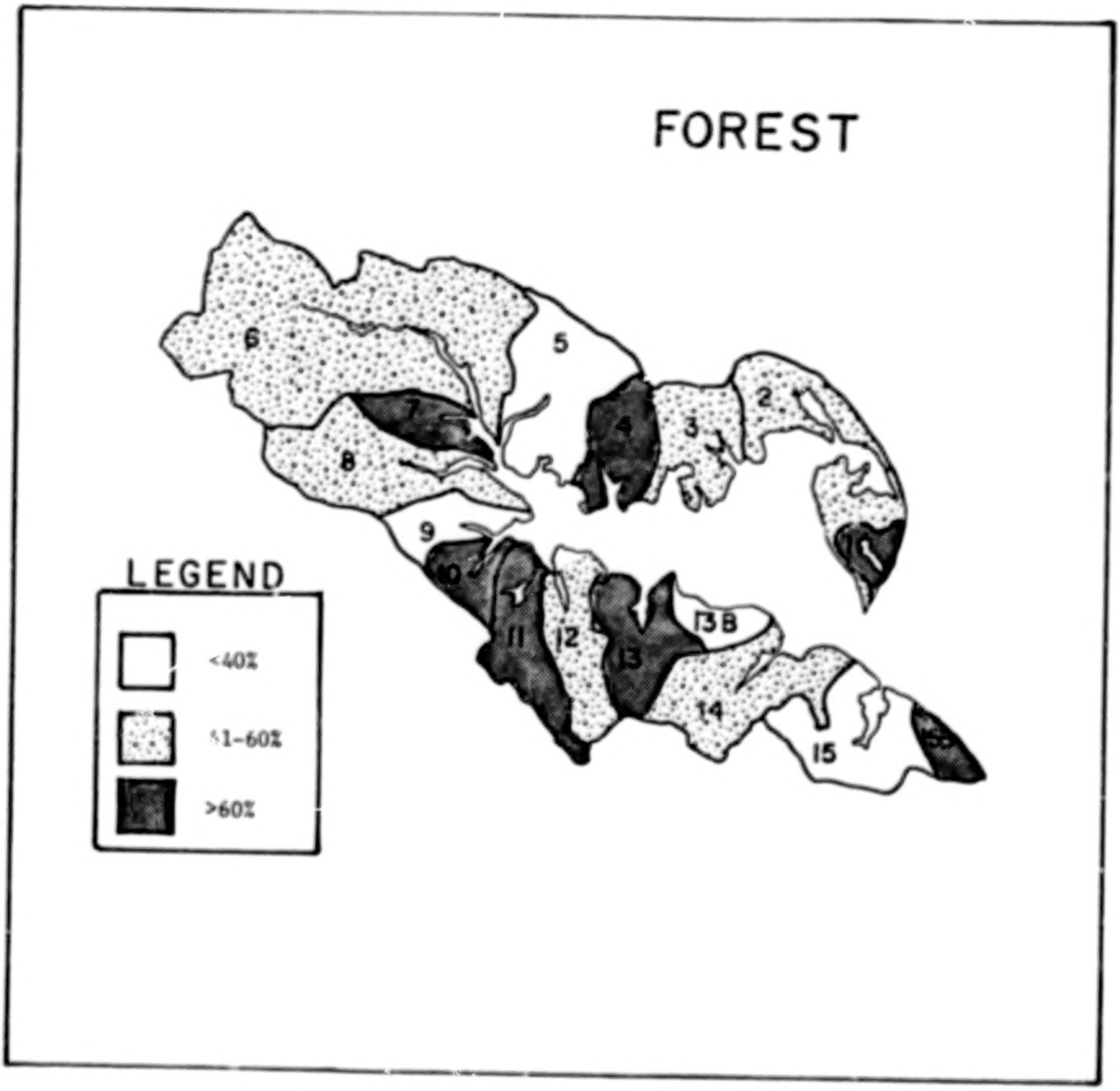
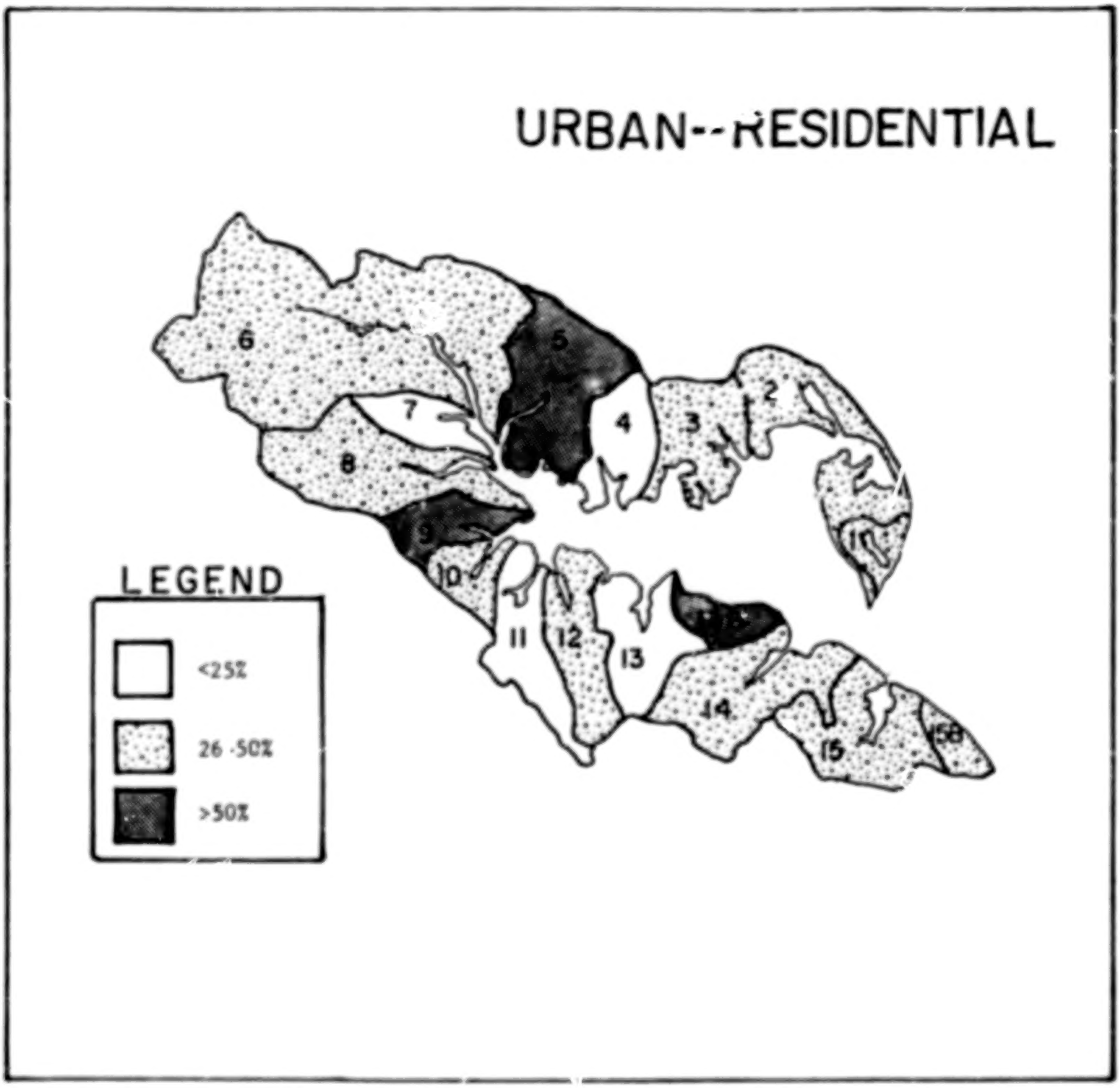

FOREST
6
5
7
8
4
3
2
9
10
11
12
13
13B
14
15
LEGEND
<40%
41-60%
>60%

FIGURE 27

PERCENT URBAN/RESIDENTIAL AREA - MAGOTHY RIVER SUB-BASIN


URBAN--RESIDENTIAL
6
5
7
4
3
2
8
9
10
11
12
13
14
15
15B
LEGEND
<25%
26-50%
>50%

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APPENDIX A: ECHOS MODEL DESCRIPTION

APPENDIX B: RPC RESPONSE TO MAGOTHY RIVER ANALYSIS

FIGURE 28

PERCENT AGRICULTURE - PASTURE AREA - MAGOTHY RIVER SUBBASINS

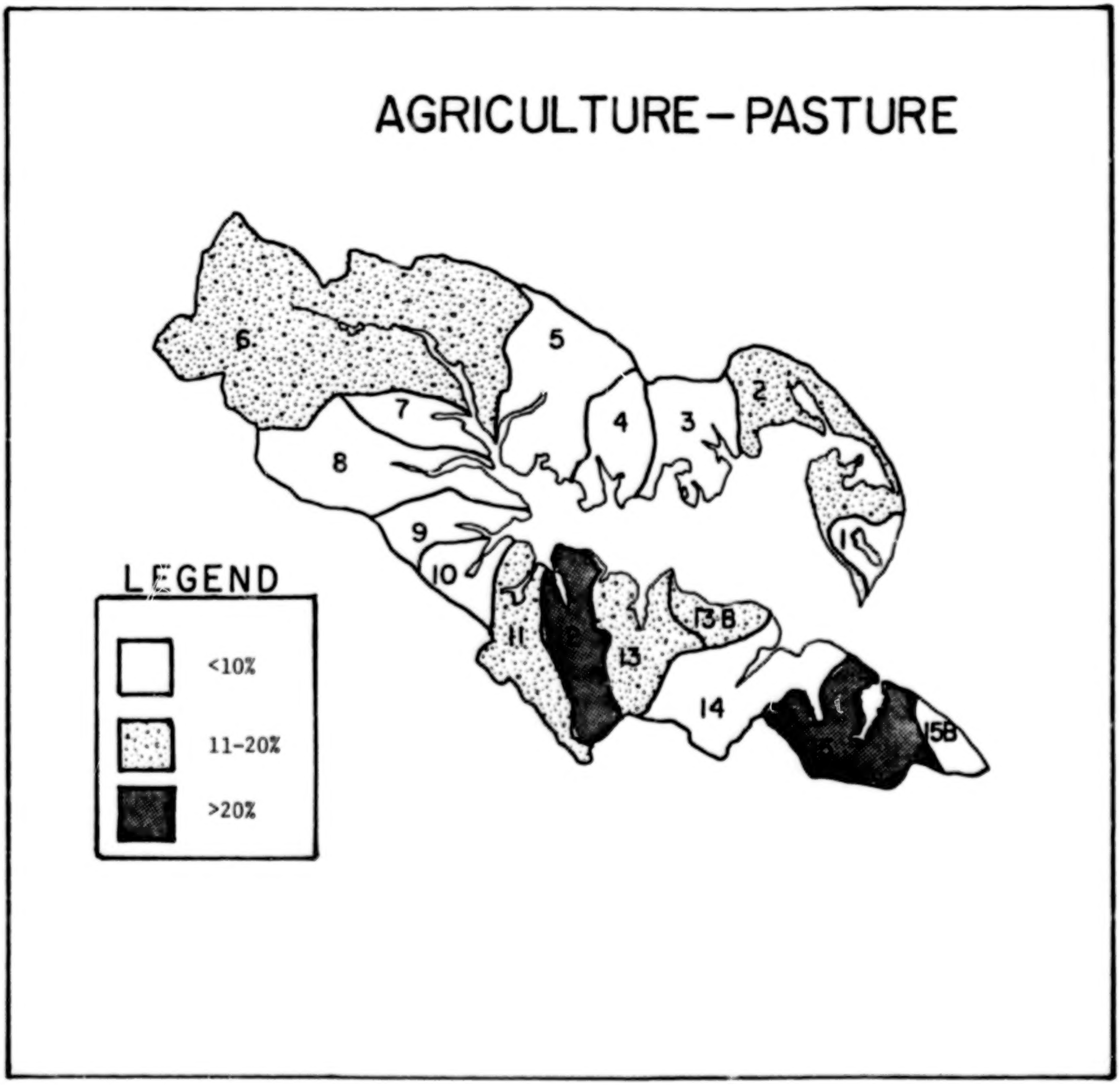
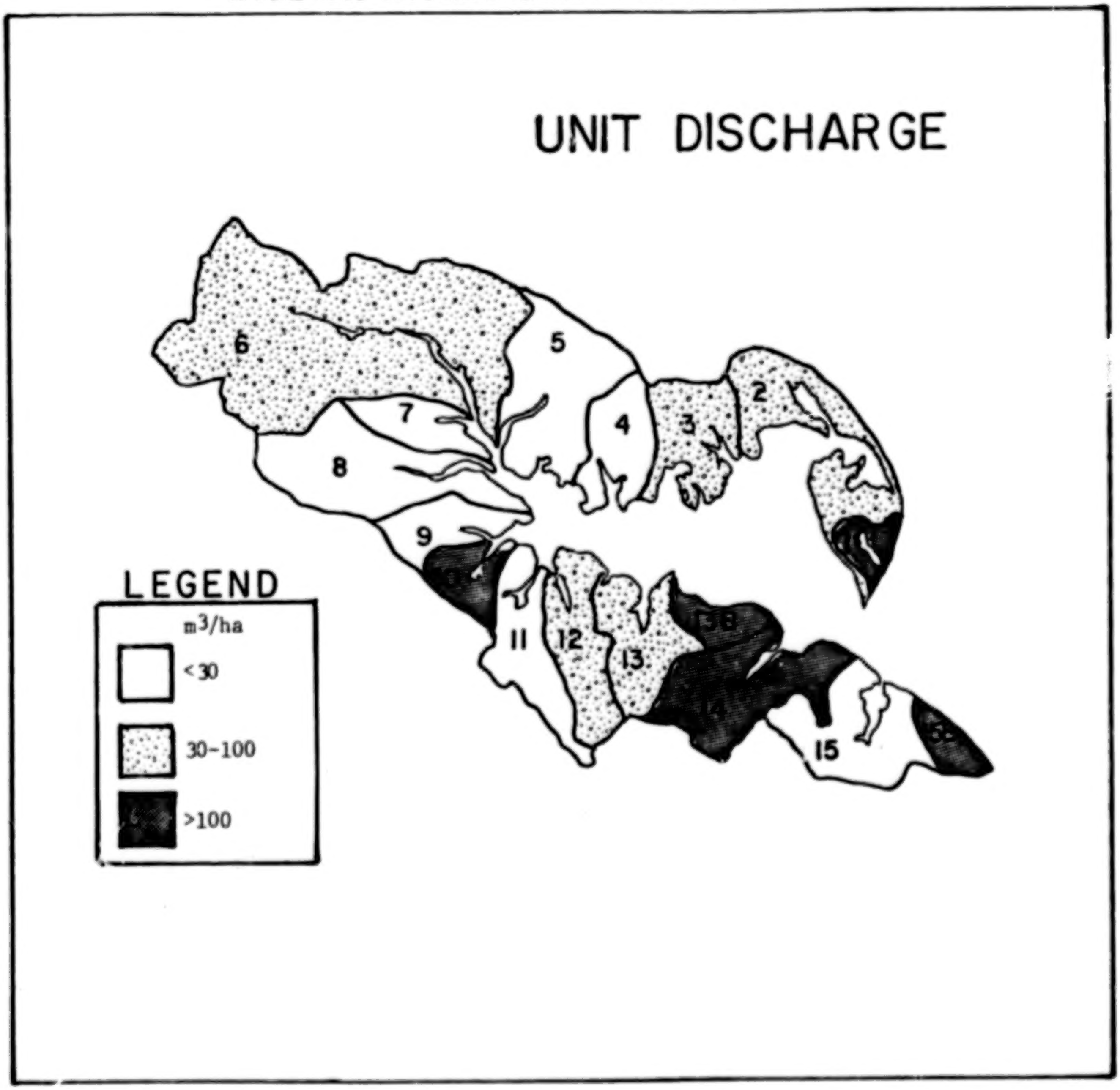

AGRICULTURE-PASTURE
1
2
3
4
5
6
7
8
9
10
11
12
13
13B
14
15B
LEGEND
<10%
11-20%
>20%

FIGURE 29

ANNUAL UNIT DISCHARGE-MAGOTHY RIVER SUBBASINS


UNIT DISCHARGE
6
5
7
4
3
2
8
9
11
12
13
3B
14
15
LEGEND
m³/ha
<30
30-100
>100

than flow. As shown in Table XVIII, seven of the Magothy River sub-basins produced pollutant loads which could not fully be explained by unit discharge. Mill Creek, for example, did not behave like the flow dominant Blackhole sub-basin. The unexpectedly high values of suspended solids, COD, TKN, and phosphorous result from the high proportion of pasture present rather than unit discharge. This exemplifies the importance of adequate land use data to non-point source pollutant modelling.

TABLE XVIII

MAGOTHY RIVER SUB-BASINS - DRIVERS OF POLLUTANT LOADING

SUBBASIN	TSS	BOD	COD	TKN	TN	TP	UNIT DISCHARGE	POLLUTANT LOAD DRIVER
1. Otter Pond	H	H	H	H	H	H	H	Runoff
2. Cornfield	H-M	M	M	M	L-M	M	M	Runoff
3. Gray's Creek	H-M	M	M	M	L-M	M	M	Runoff
4. Black Hole Creek	L	L	L	L	L	L	L	Runoff
5. Cockey Creek	M	M	L	M	M	L	L	Medium Values due to 7% Pasture
6. Lake Waterford	H	M	M	M	M	M	M	High TSS due to 6% agriculture
7. Old Man Creek	L-M	L	L	L	L	L	L	Runoff
8. Cattail Creek	L	L	L	L	L	L	L	Runoff
9. Cape Arthur	M	L	M	L	L	L	L	Medium values due to 12% strip commercial
10. Cypress Creek	H	H	H	H	H-M	H	H	Runoff
11. Dividing Creek	L-M	L-M	L-M	L	L	L	L	Low-Medium values due to 1% strip commercial
12. Mill Creek	H	M	H	H	M	H	M	High values due to 20% pasture
13. Forked Creek	H	M	H	H	M	H	M	High values due to 11% pasture, 3% strip commercial
13B. Bayberry	H	H	H	H	H	H	H	Runoff
14. Deep Creek	H	H	H	H	H	H	H	Runoff
15. L. Magothy River	H	L	M	L	L	M	L	Medium, High values due to 6% agriculture; 25% pasture
15B. Tydings	H	H	H	H	M-H	H	H	Runoff

VII. THE USE OF THE LANDSAT DERIVED POLLUTANT LOAD AT RPC

The resolution of region-wide land cover measurement and concommitant non-point source pollutant load assessment has had a beneficial impact upon "208" planning work. Prior to demonstration of optical classification techniques using LANDSAT data, a major concern over project implementation had existed. The RPC now feels it has at its disposal techniques which greatly reduce the analytic effort while maintaining satisfactory precision.

Using a hybrid procedure of LANDSAT and aerial remote sensing, land use analysis can be accomplished to the required level of detail (Level 1) in very short time for small areas. Basins of size comparable to the Magothy could be analyzed by one person in approximately three days after the imagery has been received and prepared. An opportunity for resource savings exists. Using computer classification of LANDSAT CCT, accurate land use data for the total region and larger areas within the region have been generated.

Response to these procedures by the RPC personnel has been favorable. The work performed on the Magothy has been included in the RPC's draft "208" plan as indicated in the following section.

7.1 Excerpt from the RPC "208" Plan

Magothy River Pollutant Load Analysis (Note figures not included)

The analysis of water quality samples during wet weather conditions is important for an accurate understanding of non-point sources of pollution. The cost of wet weather quality sampling, however, is extremely high.

An alternative to the actual collection of wet weather water quality data is the development and calibration of a computer model which simulates natural stream conditions. This approach is being demonstrated through a special analysis of the Magothy River Watershed.

The computer model developed for the Magothy River Watershed uses land cover data from LANDSAT satellite imagery and aerial photography, pollutant load data, and rainfall and runoff records. The model calculates wet weather pollutant loadings, using these data.

The steps followed in developing and applying the computer model for the Magothy River are listed below:

1. Land Use Analysis from LANDSAT and Aerial Imagery:

   The remote sensing analysis of the Magothy River watershed was completed during the January reporting period.

   The procedure first required the preparation of satellite and aerial imagery into color slide form, as described in the December report. Subsequently, a preliminary examination of the aerial scene containing the Magothy River was made. It was determined that seven general land use classes were present: residential, commercial/industrial, extractive, agriculture, water, forests, and pasture/grass areas.

   The entire Magothy River Watershed was mapped and classified from the aerial photo. Because of the age of the aerials (September, 1970), imagery from 1975 was acquired from the Baltimore RPC, and the ground truth map updated. Changes had to be made in about ten areas reflecting new residential or commercial development.

   Test sites were then selected for each class. This area constituted about two to three percent of the total watershed. A map was prepared locating the sites and the watershed boundary.

This map was used as the basis for LANDSAT classifications of land use. Each satellite scene was projected over the map of test sites and the colors of each class were recorded. The images of May, August, and October, 1975, February, 1974, and April and October, 1973 were used. This information was then used to determine which scenes were preferable for identifying different land use classes. For example, forest appeared dark in the February, 1974, scene while potential confusers were lighter. This image was therefore used to segregate forest. Similar logic was applied to separation of the other land use classes.

High color contrast in the October 6, 1973 scene allowed the relatively easy separation of the extractive and commercial/industrial classes. The negative image of October 6 showed water as bright white; it was therefore readily separated. Three classes - residential, pasture/grass, and agricultural - then remained to be segregated. No single image shows agricultural areas in marked contrast with the other classes. Therefore, the temporal characteristics of cropped fields had to be relied upon. By examination of all the available scenes, it was determined that agricultural areas followed a unique progression of colors: dark pink in April, light blue to white in October, and orange/light blue in February. All areas exhibiting this behavior were then classified as agricultural. No scene indicates residential areas strongly separable from pasture/grass. This is due to the low density (2-4 units per acre) of most residential development present. Some of the more densely developed residential areas could be consistently identified, but most behaved like pasture/grass areas all through the year. The total residential fraction could not be segregated to the accuracies required by the Regional Planning Council. It was decided, therefore, to extract the residential class from the aerial photography. While the use of computer compatible tapes or additional images might permit the total classification from LANDSAT, the use of a hybrid satellite - aerial remote sensing system to derive pollution loads represents a tool useful to the Regional Planning Council.

On the basis of this technique, the land use map shown in Figure 3-B-23 was prepared. Overall classification error was 2.3%.

2. Pollution Loading Factors

Two sets of pollution loading figures received from the RPC and the Washington COG were used in the modeling. These sets of numbers were reasonably consistent; they were used as multipliers to convert flow to kilograms of pollutants.

3. Rainfall/Runoff Records

Runoff records were received from the RPC for three separate sites: Cape St. Clair, Bay Hills, and Severna Park. Sufficient data points to plot outflow hydrographs, which matched available rainfall data, existed only for four events at Cape St. Clair.

These events were for February 24, March 18, April 2, and July 25, 1977.

In addition to on-site rainfall data, records were obtained for the Baltimore gage, giving hourly rainfall values for 1948-1974. From these data, average monthly rainfall profits were developed.

4. Model Calibration

The ECOsystems Hydrologic Simulator (ECHOS) was calibrated using the data from Cape St. Clair. The physical parameters of area, slope, flow length, and stream characteristics were taken from USGS 1:24000 topographic maps. Land cover (surface friction) came directly from the map prepared from the satellite and aerial analysis.

The four rainfall events were run and matched to actual hydrographs. Runs were made until a satisfactory fit was achieved. An example is shown in Table 3-B-15. These runs were used primarily to set the values of subsurface soil moisture depletion.

The four events, combined with the Baltimore rainfall data, were also used to set appropriate antecedent soil moisture. From the discharge record, the percentage of rainfall which became runoff was computed. The fractions derived are shown below:

February	1.0%
March	2.0%
April	1.3%
July	2.8%

From these four points, curves were extrapolated based upon comparison of rainfall columns and peak rates as derived from the 25 year Baltimore records.

It was now known, for example, that in August about 2.8 percent of rainfall would become direct runoff on the average. A second set of calibrations was then performed to set antecedent soil moisture (API) to a value that would produce the correct percentage of runoff. This was done by trial and error, setting an estimated value of API and recording the resultant runoff. The optimal set of antecedent soil moisture percent are given below:

Month	Optimal % API
January	99%
February	99
March	100
April	100
May	96
June	94
July	93
August	93

September	95
October	96
November	97
December	98

The values derived are very well balanced when considered from a hydrologic point of view. High values of soil moisture were obtained for months with lower solar radiation and ET and vice-versa.

These values were input to the ECHOS data files. The simulation of pollutant loads could now be run.

5. Model Runs

The Magothy Basin was broken down into major sub-basins. The initial run was made for sub-basin 11, Dividing Creek. ECHOS reads the rainfall profile month by month, calculates overland flow, routes the runoff through the stream channel and computes the hydrograph at the outlet. Streamflow is cumulated and converted to pollutant loads using the COG and RPC factors described earlier. Monthly loads and an average annual summary are produced.

Total loads are given by multiplying the load from the average storm by the average number of storms per month as calculated from the Baltimore data. An example of the output from the computer analysis runoff summary and pollutant loadings for the Dividing Basin during July is shown on Table 3-B-16.

7.2 The RPC's Direct Response

The favorable reaction to the Magothy River analysis stems directly from the fact that the technique was demonstrated for an area where the results would be immediately useful.

The written comments given in Appendix B were received from the RPC on the use of LANDSAT data to derive non-point source pollutant loads.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The application of LANDSAT derived data to non-point source pollutant load estimation of the Magothy Basin was successfully accomplished for the Baltimore Regional Planning Council. The pollutant loads and the LANDSAT-oriented techniques which were used to derive them have been incorporated into the current RPC "208" plan and have been selected for future broader applications at RPC. The cost-effectiveness and the applicability of the techniques for present and future use in regional NPS investigations have been judged to be excellent by the RPC personnel.

A. Significant Findings as Regards LANDSAT Derived Land Cover:

1. The relatively high cost of aerial photography and the limited frequency of total regional coverage gave rise to the need for LANDSAT-oriented land cover classification techniques. The need for accurate sub-basin land use data requires an improvement over conventional land use estimates with large cell size. LANDSAT computer classifications are adequate for large area estimates, but exhibit relatively high errors for small areas. The development of a hybrid, LANDSAT-optical technique with minimum aerial coverage input for residential areas proved a successful, cost-effective solution to the problems in the Baltimore RPC area.

2. Average errors of less than 5% were obtained for the four small areas investigated in these studies. The area evaluated ranged from 108 hectares to 8,600 hectares.

3. Accuracies obtained by this hybrid analysis technique were commensurate with the error budget adopted for non-point source pollutant load estimation by the RPC.

B. Significant Findings as Regards Pollutant Loads for the Magothy Protypical Area Include:

1. Annual pollutant loads from storms resulting from the average rainfall were computed to be: 615.3 metric tons per year of total suspended solids, 26.5 metric tons per year of BOD, 344.7 metric tons per year of

COD, 6.3 metric tons per year of TKN, 9.5 metric tons per year of total nitrogen and 1.4 metric tons per year of total phosphorous.

2. The major period of storm load contribution was the period of July through September. The characteristic occurrence of high intensity storms in this period accounted for 70% of the total storm load.

3. High unit pollutant loads were computed for the following sub-basins of the Magothy: Otter Pond, Cypress Creek, Mill Creek, Bayberry, Deep Creek and Tydings. These sub-basins total 31% of the total area of the Magothy.

C. Significant Findings as Regards the Application of Hydrologic Models Based Upon Satellite Data for Non-Point Source Load Estimation

1. A simple, useful, and cost-effective modeling procedure has been developed to estimate annual and event-oriented pollutant loads from storms, using specific or generalized pollutant load coefficients.

2. The procedure is based upon land cover data derived from satellite images.

3. The accuracy levels of the procedure is commensurate with the accuracy level of the input pollutant data.

4. The procedure provides environmental and land use planners with practical, easily adopted techniques from which to estimate the sensitivity of specific watersheds to current and future land use distributions and patterns.

5. The model developed has been made extremely flexible to accommodate the maximum user-derived inputs.

6. Techniques for estimating the input parameters for areas with limited data have also been developed and demonstrated.

The experience gained during this technology transfer project supports the expectation which surround the availability of frequent accurate land cover data from satellites such as LANDSAT. The user population is large and widespread. Certain problems like those engendered by the EPA "208" program are immediately amenable to solutions using LANDSAT data.

Technology transfer requires that not only the user be made familiar with the LANDSAT products but that he also be aided in developing the models, techniques and algorithms necessary for its successful employment. Most users are not engaged in pure research pursuits and hence require "proof" before committing these resources to the use of a new and not as yet proven sources of data. Once these problems are overcome, however, the users are quick to grasp and improve the use of the data.

1. It is recommended that the procedures developed herein be made available to a broad spectrum of "208"-type users.
2. It is further recommended that the utility of pollutant load estimation techniques be tested for the so-called non-designated areas throughout the U.S. where data is much less available than in designated regional areas such as the Baltimore RPC.
3. The correlative parameter in this pollutant load model was chosen to be total runoff from an event due to the unavailability of flow to load correlations. It is recommended that further simulations be carried on as these data become available and that a concomitant expansion of the rainfall recurrence case be considered to include expected non-linearit in the flow-to-load relationships.
4. Following the suggestions given by the Baltimore RPC, it is recommended that a procedural handbook be prepared illustrating the application of LANDSAT data to non-point pollution estimation for subsequent transmittal to the large user audience throughout the U.S.

APPENDIX A: ECHOS MODEL DESCRIPTION

- DESCRIPTION OF THE MODEL
- SAMPLE OUTPUT
- FORTRAN LISTING

Description of the Model

The ECOsystems Hydrologic Simulator (ECHOS) requires that the following data about each sub-basin be known or estimated:

1. Average slope, m/m
2. Area, m^2
3. Average Overland Flow Length, m
4. Width (equal to area ÷ flow length), m
5. Average Mannings "n"
6. Soil Moisture Capacity, m
7. Antecedent Moisture Content, m
8. Final (saturated) Infiltration Rate, m/sec.
9. Percolation Rate, m/m
10. Detention Storage, m

Additionally, these data are required for each stream segement:

1. Length, m
2. Average slope, m
3. Channel width, m
4. Channel Manning's "n"

As adapted for the Baltimore RPC, (Version 1P) data are also required giving pollutant loading factors for two sets of land use classification, one supplied by RPC and one received from the Washington Council of Government (COG):

RPC Classes

Rural (∿ 4% impervious)

Low Activity Commercial (∿ 12% impervious)

Low Activity Residential (∿ 16% impervious)

High Activity Commercial (∿ 35% impervious)

High Activity Residential (∿ 32% impervious)

Central Business District (∿ 80% impervious)

COG Classes

Shopping Centers

Strip Commercial

High Rise Residential

Town House/ Garden Apartments

Med. Density Single Family Residential

Construction

Forest

Conventional Tillage Agriculture

Minimum Tillage Agriculture

Pasture

The program is written in language. It is presently configured for a PDP 11-34, 32K computer but has also run on IBM and Honeywell machines of comparable size.

The program reads the data it requires out of separate files prepared in advance of a run on disk or tape. Four files are involved; for the Magothy River they have been called DATA.DAT, RAIN.DAT, LINK.DAT, and CON.DAT. Examples of each are given in Table AI a,b,c, and d.

DATA.DAT contains values for all the physiographic parameters of each sub-basin and stream. It also includes the initial conditions of the simulation and time-keeping information. RAIN.DAT contains a set of intensities and corresponding durations for each month. LINK.DAT gives the program the connection between sub-basins and channels, i.e., it identifies which basins flow into which streams. CON.DAT contains the pollutant loading factors and land use fractions for the RPC and COG data.

A simplified flow chart for ECHOS is shown in Figure 1A. Briefly, the model reads the first rainfall profile and the parameters for the first sub-basin. It computes overland flow and stores it as elements of a flow-versus-time matrix. The process is repeated for each sub-basin. Subsequently, the model rates the output of the appropriate sub-basin or sub-basins through the channel or channels as specified by LINK.DAT. Flow is routed until the basin outlet has been reached. A table is then printed out giving time since the start of rainfall, rain and discharge rate, and cumulative rain and discharge. Finally, total discharges for the month are computed and converted to pollutant loads using the loading factors

TABLE A1

DATA FILES

```
 REENTER
*ERDX1:CON.DAT$EWDX1:CON.DAT$R$B$/L$$
04191006.500000000.002553903.300000000.000000000.000000000.0
0167.000007.000038.200000.710000.41
0239.000007.600061.100001.030000.47
0293.000007.700076.100002.320000.49
0751.000012.200140.600002.340000.68
0633.000013.200172.800002.220000.60
0179.000015.300178.200002.970000.46
00000000.000000000.000000000.000000000.000000000.002553903.3
00000000.003443794.600000000.000000000.000747211.9
0074.000054.660001.810002.430000.20
0098.000111.530001.330001.760000.27
0034.000096.280000.870001.200000.22
0115.000073.460001.120001.490000.29
0042.000095.880001.940002.420000.38
0142.000115.150002.760003.640000.35
0763.000089.350001.610001.760000.26
0000.000072.400001.280001.300000.12
1681.000853.380008.900013.420003.18
0133.000086.240001.930003.520001.14
0544.000549.000004.970005.160001.06
```

```
.R EDIT
*ERDX1:DATA.DAT$EWDX1:DATA.DAT$R$B$/L$$
01015.0600000000.0.00000
00540.140.0170.066012478..002500000.0380000000.0000002420.000018056
CORNFLD 06744909.8
01
01000.000.0040.0382.00
*EX$$
```

```
 R EDIT
*ERDX1:LINK.DAT$EWDX1:LINK.DAT$R$B$/L$$
EAST
0001DUMMY
01
*EX$$
```

A

```
00.9908.14JANUARY 18032400
.00000003601800.
.00000010701800.
.00000017901800.
.00000025001800.
.00000032201800.
.00000039301800.
.00000047201800.
.00000045101800.
.00000041501800.
.00000037201800.
.00000032901800.
.00000028601800.
.00000023601800.
.00000019301800.
.00000015001800.
.00000010701800.
.00000006401800.
.00000002101800.
00.9907.63FEBRUARY16028800
.00000004201800.
.00000012501800.
.00000022201800.
.00000030601800.
.00000033401800.
.00000047201800.
.00000055601800.
.00000066701800.
.00000061101800.
.00000052801800.
.00000044401800.
.00000036101800.
.00000027801800.
.00000019401800.
.00000011101800.
.00000004201800.
01.0008.78MARCH     16028800
.00000005201800.
.00000015701800.
.00000026201800.
.00000036701800.
.00000047101800.
.00000057601800.
.00000063901800.
.00000062101800.
.00000054601800.
.00000047101800.
.00000040401800.
.00000033701800.
.00000026201800.
.00000018701800.
.00000011201800.
.00000003701800.
01.0010.24APRIL     13023400
.00000005101800.
.00000016601800.
.00000027501800.
.00000039001800.
.00000049801800.
.00000060701800.
.00000072201800.
.00000052401800.
.00000042001800.
.00000033201800.
.00000023601800.
.00000014701800.
.00000005101800.
```

B

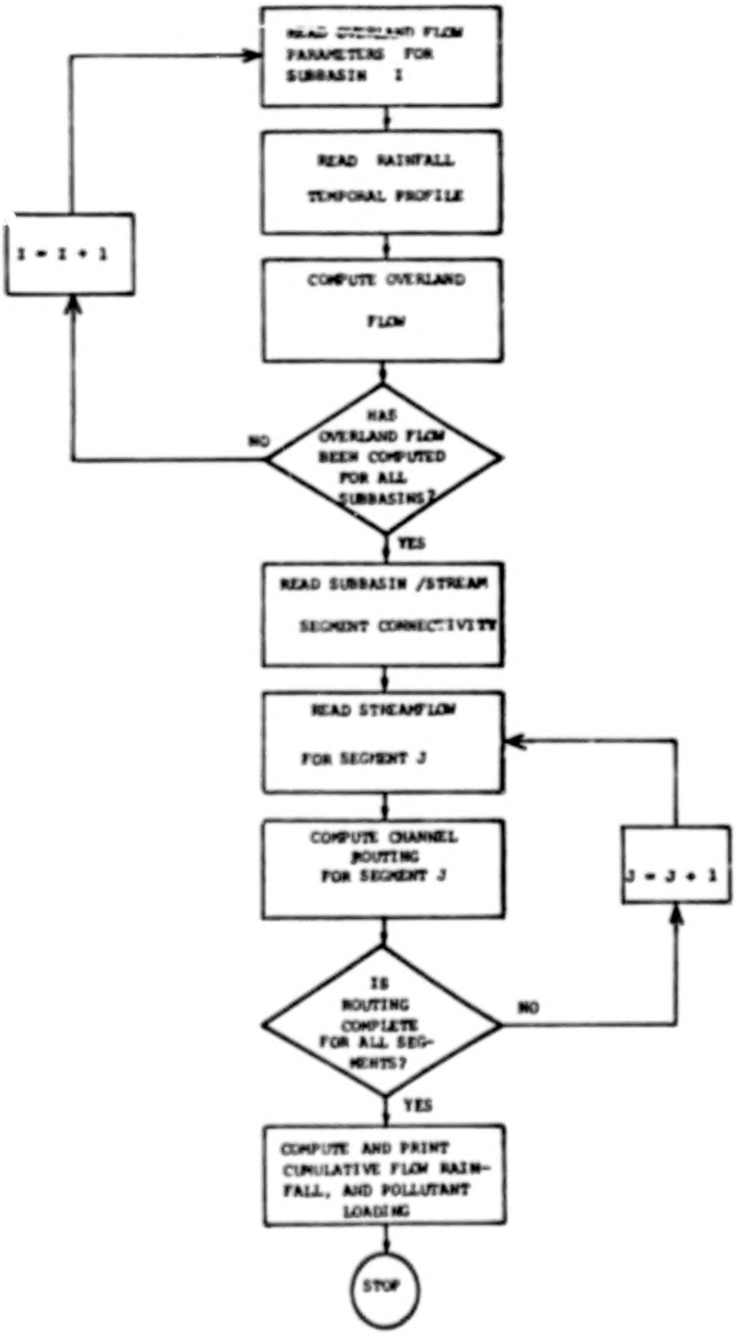
```
00.9610.52MAY       10018000
.00000009401800.
.00000028101800.
.00000046901800.
.00000065701800.
.00000083101800.
.00000100001800.
.00000071001800.
.00000049601800.
.00000029501800.
.00000009401800.
00.9409.65JUNE      14012600
.00000011000900.
.00000032900900.
.00000054900900.
.00000076800900.
.00000098800900.
.00000120700900.
.00000132000900.
.00000132000900.
.00000114400900.
.00000095600900.
.00000073700900.
.00000051700900.
.00000032900900.
.00000011000900.
00.9309.11JULY      14012600
.00000012300900.
.00000035400900.
.00000058500900.
.00000081600900.
.00000104800900.
.00000127900900.
.00000151000900.
.00000169400900.
.00000132500900.
.00000113700900.
.00000084300900.
.00000059900900.
.00000036700900.
.00000012300900.
00.9309.46AUGUST    16014400
.00000010300900.
.00000032300900.
.00000053900900.
.00000077000900.
.00000100100900.
.00000121700900.
.00000143200900.
.00000159500900.
.00000159500900.
.00000146300900.
.00000123200900.
.00000100100900.
.00000078500900.
.00000055400900.
.00000033900900.
.00000010300900.
```

C

```
00.9507.29SEPTEMBE11019800
.00000010401800.
.00000031201800.
.00000050501800.
.00000071301800.
.00000092101800.
.00000099001800.
.00000083201800.
.00000065301800.
.00000046001800.
.00000028201800.
.00000008901800.
00.9606.60OCTOBER 15027000
.00000006201800.
.00000018601800.
.00000030901800.
.00000043301800.
.00000055701800.
.00000068101800.
.00000088001800.
.00000073001800.
.00000059401800.
.00000050701800.
.00000040801800.
.00000032201800.
.00000023501800.
.00000013601800.
.00000005001800.
00.9706.78NOVEMBER17030600
.00000005501800.
.00000014301800.
.00000023101800.
.00000033001800.
.00000042901800.
.00000051701800.
.00000061401800.
.00000085301800.
.00000059401800.
.00000051701800.
.00000045101800.
.00000038501800.
.00000031901800.
.00000024201800.
.00000017601800.
.00000009901800.
.00000003301800.
00.9807.46DECEMBER22039600
.00000003801800.
.00000011401800.
.00000018201800.
.00000025301800.
.00000032501800.
.00000040101800.
.00000047701800.
.00000104501800.
.00000054501800.
.00000050701800.
.00000046101800.
.00000042401800.
.00000038601800.
.00000034001800.
.00000030301800.
.00000026501800.
.00000021901800.
.00000018201800.
.00000014401800.
.00000007901800.
.00000006101800.
.00000002301800.
```

FIGURE 1A

ECHOS MODEL: SIMPLIFIED FLOW CHART


READ OVERLAND FLOW PARAMETERS FOR SUBBASIN I
READ RAINFALL TEMPORAL PROFILE
I = I + 1
COMPUTE OVERLAND FLOW
HAS OVERLAND FLOW BEEN COMPUTED FOR ALL SUBBASINS?
NO
YES
READ SUBBASIN /STREAM SEGMENT CONNECTIVITY
READ STREAMFLOW FOR SEGMENT J
COMPUTE CHANNEL ROUTING FOR SEGMENT J
J = J + 1
IS ROUTING COMPLETE FOR ALL SEGMENTS?
NO
YES
COMPUTE AND PRINT CUMULATIVE FLOW RAINFALL, AND POLLUTANT LOADING
STOP

of CON.DAT. Tables showing the monthly loads for organic pollutant are then output. (A detailed description of the d derivation of ECHOS is given in the final report of NAS8-30539, 24 February, 1977).

Table AII is a sample output of the model for the Dividing Creek sub-basin of the Magothy River. The output derived from the file data is shown in Table A1 a through d.

Table AIII gives a listing of ECHOS, Version 1P.

TABLE AII: SAMPLE OUTPUT; ECHOS MODEL

```
                               ECOSYSTEMS HYDROLOGIC SIMULATOR (ECHOS)
                                               VERSION 1P


****************************************************************************************************
* SUBBASIN: EAST                                                                                   *
* LENGTH=   504.13 METERS  SLOPE= 0.033  N= 0.056  WIDTH=   2456.METERS  DETENTION=0.00250 METERS  *
* SOIL  MOISTURE CAPACITY = 0.050000001 METERS     ANTECEDENT SOIL MOISTURE= 0.049500000 METERS    *
* PERCOLATION RATE= 0.000000220 M/SEC              FINAL INFILTRATION RATE= 0.000012500 M/SEC      *
****************************************************************************************************

****************************************************************************************************
* SUBBASIN: WEST                                                                                   *
* LENGTH=   594.15 METERS  SLOPE= 0.037  N= 0.085  WIDTH=   4568.METERS  DETENTION=0.00250 METERS  *
* SOIL  MOISTURE CAPACITY = 0.044000000 METERS     ANTECEDENT SOIL MOISTURE= 0.043560002 METERS    *
* PERCOLATION RATE= 0.000000238 M/SEC              FINAL INFILTRATION RATE= 0.000013900 M/SEC      *
****************************************************************************************************

****************************************************************************************************
* STREAM SEGMENT: DIVID CK                                                                         *
* LENGTH=  3963.41METERS          SLOPE= 0.010          N= 0.038          WIDTH= 2.00METERS        *
****************************************************************************************************
```

```
                         RUNOFF SUMMARY FOR DIVIDECK BASIN
                            AVG. EVENT FOR: JANUARY
                           AVG. NO. OF STORMS:  8.14

     TIME           DISCHARGE          RAIN RATE          CUMULATIVE          CUMULATIVE
    (SECS)           (M3/S)              (M/S)          DISCHARGE(M3)        RAINFALL(M3)


      900.        0.00000000        0.0000000360          0.0000              128.0342
     1800.        0.00000000        0.0000000360          0.0000              256.0684
     2700.        0.00000000        0.0000001070          0.0000              636.6145
     3600.        0.00000000        0.0000001070          0.0000             1017.1606
     4500.        0.00000000        0.0000001790          0.0000             1653.7751
     5400.        0.00000000        0.0000001790          0.0000             2290.3896
     6300.        0.00000000        0.0000002500          0.0000             3179.5161
     7200.        0.00000000        0.0000002500          0.0000             4068.6426
     8100.        0.00000000        0.0000003220          0.0000             5213.8374
     9000.        0.00000000        0.0000003220          0.0000             6359.0322
     9900.        0.00000000        0.0000003930          0.0000             7756.7388
    10800.        0.00000000        0.0000003930          0.0000             9154.4453
    11700.        0.00000000        0.0000004720          0.0000            10833.1162
    12600.        0.00000000        0.0000004720          0.0000            12511.7871
    13500.        0.00000000        0.0000004510          0.0000            14115.7715
    14400.        0.00000000        0.0000004510          0.0000            15719.7549
    15300.        0.00000000        0.0000004150          0.0000            17195.7051
    16200.        0.00000000        0.0000004150          0.0000            18671.6543
    17100.        0.00000000        0.0000003720          0.0000            19994.6738
    18000.        0.00000000        0.0000003720          0.0000            21317.6953
    18900.        0.00000000        0.0000003290          0.0000            22487.7852
    19800.        0.00000000        0.0000003290          0.0000            23657.8770
    20700.        0.00000000        0.0000002860          0.0000            24675.0371
    21600.        0.00000000        0.0000002860          0.0000            25692.1973
    22500.        0.00000000        0.0000002360          0.0000            26531.5332
    23400.        0.00000000        0.0000002360          0.0000            27370.8672
    24300.        0.00000000        0.0000001930          0.0000            28057.2734
    25200.        0.00000000        0.0000001930          0.0000            28743.6777
    26100.        0.00000000        0.0000001500          0.0000            29277.1543
    27000.        0.00000000        0.0000001500          0.0000            29810.6289
    27900.        0.00000000        0.0000001070          0.0000            30191.1758
    28800.        0.00000000        0.0000001070          0.0000            30571.7207
    29700.        0.00000000        0.0000000640          0.0000            30799.3379
    30600.        0.00000000        0.0000000640          0.0000            30926.9531
    31500.        0.00000000        0.0000000210          0.0000            31103.6406
    32400.        0.00000000        0.0000000210          0.0000            31176.3262
```

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                  +
+                                                                                                  +
+                                 POLLUTANT LOADING: DIVIDECK BASIN                                +
+                                       EVENTS OF: JANUARY                                         +
+                                     RPC CONCENTRATION DATA                                       +
+                                                                                                  +
+                                                                                                  +
+           LAND USE: RURAL=  0.92! LAC=  0.01! LAR=  0.06! HAC=  0.00! HAR=  0.00! CBD=  0.00     +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED      BOD       COD       TOTAL KJELDAHL       TOTAL           +
+         LOAD-KGS.        SOLIDS                             NITROGEN             PHOSPOROUS      +
+                                                                                                  +
+                                                                                                  +
+                              0.000     0.000      0.000            0.000                0.000    +
+                                                                                                  +
+                                                                                                  +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                  +
+                                                                                                  +
+                                     COG CONCENTRATION DATA                                       +
+                                                                                                  +
+                                                                                                  +
+         LAND USE: SHOP CTR=  0.00! STRP COM=  0.01! HR RES=  0.00! TH/GA=  0.00! MDSFR=  0.00    +
+                   LLSFR=  0.06! CON=  0.00! FOR=  0.82! CT AG=  0.00! MT AG=  0.00! PAST=  0.10  +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED      COD       TOTAL KJELDAHL       TOTAL       TOTAL         +
+         LOAD-KGS.        SOLIDS                   NITROGEN             NITROGEN    PHOSPOROUS    +
+                                                                                                  +
+                                                                                                  +
+                              0.000      0.00            0.000            0.000          0.000    +
+                                                                                                  +
+                                                                                                  +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                            +
+                                                                                            +
+                          RUNOFF SUMMARY FOR DIVIDECK BASIN                                 +
+                             AVG. EVENT FOR: FEBRUARY                                       +
+                            AVG. NO. OF STORMS:   7.63                                      +
+                                                                                            +
+                                                                                            +
+       TIME          DISCHARGE         RAIN RATE          CUMULATIVE         CUMULATIVE     +
+      (SECS)           (M3/S)            (M/S)          DISCHARGE(M3)       RAINFALL(M3)    +
+                                                                                            +
+                                                                                            +
+        900.       0.00000000       0.0000000420          0.0000             149.3732      +
+       1800.       0.00000000       0.0000000420          0.0000             298.7465      +
+       2700.       0.00000000       0.0000001250          0.0000             743.3097      +
+       3600.       0.00000000       0.0000001250          0.0000            1187.8729      +
+       4500.       0.00000000       0.0000002220          0.0000            1977.4172      +
+       5400.       0.00000000       0.0000002220          0.0000            2766.9614      +
+       6300.       0.00000000       0.0000003060          0.0000            3855.2522      +
+       7200.       0.00000000       0.0000003060          0.0000            4943.5430      +
+       8100.       0.00000000       0.0000003340          0.0000            6131.4160      +
+       9000.       0.00000000       0.0000003340          0.0000            7319.2886      +
+       9900.       0.00000000       0.0000004720          0.0000            8997.9590      +
+      10800.       0.00000000       0.0000004720          0.0000           10676.6299      +
+      11700.       0.00000000       0.0000005560          0.0000           12654.0469      +
+      12600.       0.00000000       0.0000005560          0.0000           14631.4639      +
+      13500.       0.00000000       0.0000006670          0.0000           17003.6523      +
+      14400.       0.00000000       0.0000006670          0.0000           19375.8418      +
+      15300.       0.00000000       0.0000006110          0.0000           21548.8672      +
+      16200.       0.00000000       0.0000006110          0.0000           23721.8926      +
+      17100.       0.00000000       0.0000005280          0.0000           25599.7285      +
+      18000.       0.00000000       0.0000005280          0.0000           27477.5625      +
+      18900.       0.00001425       0.0000004440          0.0128           29056.6504      +
+      19800.       0.00033558       0.0000004440          0.3148           30635.7402      +
+      20700.       0.00169698       0.0000003610          1.8421           31919.6387      +
+      21600.       0.00542458       0.0000003610          6.7242           33203.5391      +
+      22500.       0.01116251       0.0000002780         16.7705           34192.2461      +
+      23400.       0.01898889       0.0000002780         33.8605           35180.9570      +
+      24300.       0.02618044       0.0000001940         57.4229           35870.9180      +
+      25200.       0.03221604       0.0000001940         86.4173           36560.8828      +
+      26100.       0.03465437       0.0000001110        117.6063           36955.6562      +
+      27000.       0.03447625       0.0000001110        148.6349           37350.4258      +
+      27900.       0.03222093       0.0000000420        177.6337           37499.8008      +
+      28800.       0.02927647       0.0000000420        203.9625           37649.1719      +
+                                                                                            +
+                                                                                            +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                    +
+                                                                                                    +
+                                 POLLUTANT LOADING: DIVIDECK BASIN                                  +
+                                       EVENTS OF: FEBRUARY                                          +
+                                    RPC CONCENTRATION DATA                                          +
+                                                                                                    +
+                                                                                                    +
+           LAND USE: RURAL=  0.92! LAC=  0.01! LAR=  0.06! HAC=  0.00! HAR=  0.00! CBD=  0.00       +
+                                                                                                    +
+                                                                                                    +
+         POLLUTANT:        SUSPENDED       BOD        COD        TOTAL KJELDAHL       TOTAL         +
+         LOAD-KGS.         SOLIDS                                NITROGEN             PHOSPOROUS    +
+                                                                                                    +
+                                                                                                    +
+                             274.036     10.978     63.728            1.272                 0.647   +
+                                                                                                    +
+                                                                                                    +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+                                                                                                    +
+                                                                                                    +
+                                    COG CONCENTRATION DATA                                          +
+                                                                                                    +
+                                                                                                    +
+         LAND USE: SHOP CTR=  0.00! STRP COM=  0.01! HR RES=  0.00! TH/GA=  0.00! MDSFR=  0.00      +
+                   LLSFR=  0.06! CON=  0.00! FOR=  0.82! CT AG=  0.00! MT AG=  0.00! PAST=  0.10    +
+                                                                                                    +
+                                                                                                    +
+         POLLUTANT:        SUSPENDED       COD        TOTAL KJELDAHL       TOTAL       TOTAL        +
+         LOAD-KGS.         SOLIDS                     NITROGEN             NITROGEN    PHOSPOROUS   +
+                                                                                                    +
+                                                                                                    +
+                              99.254     190.49            2.704            2.855           0.356   +
+                                                                                                    +
+                                                                                                    +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                    RUNOFF SUMMARY FOR DIVIDECK BASIN
                         AVG. EVENT FOR: MARCH
                        AVG. NO. OF STORMS:  8.78

     TIME          DISCHARGE          RAIN RATE           CUMULATIVE          CUMULATIVE
    (SECS)          (M3/S)              (M/S)           DISCHARGE(M3)       RAINFALL(M3)


     900.         0.00000000       0.0000000520            0.0000            184.9383
    1800.         0.00000000       0.0000000520            0.0000            369.8766
    2700.         0.00000000       0.0000001570            0.0000            928.2480
    3600.         0.00000000       0.0000001570            0.0000           1486.6194
    4500.         0.00000000       0.0000002620            0.0000           2418.4238
    5400.         0.00000000       0.0000002620            0.0000           3350.2283
    6300.         0.00000000       0.0000003670            0.0000           4655.4658
    7200.         0.00000000       0.0000003670            0.0000           5960.7036
    8100.         0.00000000       0.0000004710            0.0000           7635.8179
    9000.         0.00000000       0.0000004710            0.0000           9310.9316
    9900.         0.00000000       0.0000005760            0.0000          11359.4785
   10800.         0.00000000       0.0000005760            0.0000          13408.0264
   11700.         0.00000000       0.0000006390            0.0000          15680.6338
   12600.         0.00000000       0.0000006390            0.0000          17953.2402
   13500.         0.00000000       0.0000006210            0.0000          20161.8301
   14400.         0.00000000       0.0000006210            0.0000          22370.4199
   15300.         0.00000000       0.0000005460            0.0000          24312.2715
   16200.         0.00000701       0.0000005460            0.0063          26254.1250
   17100.         0.00030524       0.0000004710            0.2810          27929.2383
   18000.         0.00271932       0.0000004710            2.7284          29604.3535
   18900.         0.01004917       0.0000004040           11.7727          31041.1816
   19800.         0.02589324       0.0000004040           35.0766          32478.0098
   20700.         0.04984923       0.0000003370           79.9409          33676.5508
   21600.         0.08218576       0.0000003370          153.9081          34875.0937
   22500.         0.11506171       0.0000002620          257.4636          35806.8984
   23400.         0.14304954       0.0000002620          386.2082          36738.7031
   24300.         0.15575710       0.0000001870          526.3896          37403.7695
   25200.         0.15440488       0.0000001870          665.3541          38068.8359
   26100.         0.13917698       0.0000001120          790.6133          38467.1641
   27000.         0.11739077       0.0000001120          896.2650          38865.4922
   27900.         0.09321304       0.0000000370          980.1567          38997.0820
   28800.         0.07302280       0.0000000370         1045.8773          39128.6719
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*                                                                                                *
*                                                                                                *
*                               POLLUTANT LOADING: DIVIDECK BASIN                                *
*                                      EVENTS OF: MARCH                                          *
*                                  RFC CONCENTRATION DATA                                        *
*                                                                                                *
*                                                                                                *
*          LAND USE: RURAL=  0.92! LAC=  0.01! LAR=  0.06! HAC=  0.00! HAR=  0.00! CBD=  0.00    *
*                                                                                                *
*                                                                                                *
*        POLLUTANT:        SUSPENDED       BOD        COD        TOTAL KJELDAHL       TOTAL      *
*        LOAD-KGS.         SOLIDS                                NITROGEN             PHOSPOROUS *
*                                                                                                *
*                                                                                                *
*                           1616.834     64.768    376.001            7.507               3.820  *
*                                                                                                *
*                                                                                                *
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*                                                                                                *
*                                                                                                *
*                                  COG CONCENTRATION DATA                                        *
*                                                                                                *
*                                                                                                *
*        LAND USE: SHOP CTR=  0.00! STRP COM=  0.01! HR RES=  0.00! TH/GA=  0.00! MDSFR=  0.00   *
*                  LLSFR=  0.06! CON=  0.00! FOR=  0.82! CT AG=  0.00! MT AG=  0.00! PAST=  0.10 *
*                                                                                                *
*                                                                                                *
*        POLLUTANT:        SUSPENDED       COD        TOTAL KJELDAHL       TOTAL      TOTAL      *
*        LOAD-KGS.         SOLIDS                     NITROGEN             NITROGEN   PHOSPOROUS *
*                                                                                                *
*                                                                                                *
*                            385.606    1123.89           15.951           16.846         2.102  *
*                                                                                                *
*                                                                                                *
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*                                                                                                  *
*                                                                                                  *
*                               RUNOFF SUMMARY FOR DIVIDECK BASIN                                  *
*                                    AVG. EVENT FOR: APRIL                                         *
*                                 AVG. NO. OF STORMS: 10.24                                        *
*                                                                                                  *
*                                                                                                  *
*          TIME            DISCHARGE            RAIN RATE          CUMULATIVE          CUMULATIVE  *
*         (SECS)            (M3/S)                (M/S)          DISCHARGE(M3)        RAINFALL(M3) *
*                                                                                                  *
*                                                                                                  *
*           900.         0.00000000          0.0000000510          0.0000            181.3818      *
*          1800.         0.00000000          0.0000000510          0.0000            362.7636      *
*          2700.         0.00000000          0.0000001660          0.0000            953.1436      *
*          3600.         0.00000000          0.0000001660          0.0000           1543.5234      *
*          4500.         0.00000000          0.0000002750          0.0000           2521.5625      *
*          5400.         0.00000000          0.0000002750          0.0000           3499.6016      *
*          6300.         0.00000000          0.0000003900          0.0000           4886.6387      *
*          7200.         0.00000000          0.0000003900          0.0000           6273.6763      *
*          8100.         0.00000000          0.0000004980          0.0000           8044.8164      *
*          9000.         0.00000000          0.0000004980          0.0000           9815.9561      *
*          9900.         0.00000000          0.0000006070          0.0000          11974.7549      *
*         10800.         0.00000000          0.0000006070          0.0000          14133.5537      *
*         11700.         0.00000000          0.0000007220          0.0000          16701.3516      *
*         12600.         0.00000000          0.0000007220          0.0000          19269.1484      *
*         13500.         0.00000000          0.0000005240          0.0000          21132.7578      *
*         14400.         0.00000000          0.0000005240          0.0000          22996.3672      *
*         15300.         0.00000000          0.0000004280          0.0000          24518.5508      *
*         16200.         0.00000000          0.0000004280          0.0000          26040.7363      *
*         17100.         0.00000000          0.0000003320          0.0000          27221.4961      *
*         18000.         0.00000000          0.0000003320          0.0000          28402.2559      *
*         18900.         0.00000005          0.0000002360          0.0000          29241.5918      *
*         19800.         0.00000057          0.0000002360          0.0006          30080.9258      *
*         20700.         0.00000057          0.0000001470          0.0011          30603.7324      *
*         21600.         0.00000057          0.0000001470          0.0016          31126.5391      *
*         22500.         0.00000057          0.0000000510          0.0021          31307.9199      *
*         23400.         0.00000057          0.0000000510          0.0026          31489.3027      *
*                                                                                                  *
*                                                                                                  *
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*                                                                       *
*                                                                       *
*                   POLLUTANT LOADING: DIVIDECK BASIN                   *
*                          EVENTS OF: APRIL                             *
*                      RPC CONCENTRATION DATA                           *
*                                                                       *
*                                                                       *
*    LAND USE: RURAL=  0.92! LAC=  0.01! LAR=  0.06! HAC=  0.00! HAR=  0.00! CBD=  0.00   *
*                                                                       *
*                                                                       *
*   POLLUTANT:      SUSPENDED     BOD       COD       TOTAL KJELDAHL      TOTAL        *
*   LOAD-KGS.       SOLIDS                            NITROGEN            PHOSPOROUS   *
*                                                                       *
*                                                                       *
*                       0.005     0.000     0.001          0.000              0.000    *
*                                                                       *
*                                                                       *
*************************************************************************
*************************************************************************
*                                                                       *
*                                                                       *
*                      COG CONCENTRATION DATA                           *
*                                                                       *
*                                                                       *
*   LAND USE: SHOP CTR=  0.00! STRP COM=  0.01! HR RES=  0.00! TH/GA=  0.00! MDSFR=  0.00   *
*             LLSFR=  0.06! CON=  0.00! FOR=  0.82! CT AG=  0.00! MT AG=  0.00! PAST=  0.10  *
*                                                                       *
*                                                                       *
*   POLLUTANT:      SUSPENDED     COD       TOTAL KJELDAHL     TOTAL      TOTAL        *
*   LOAD-KGS.       SOLIDS                  NITROGEN           NITROGEN   PHOSPOROUS   *
*                                                                       *
*                                                                       *
*                       0.002     0.00          0.000          0.000        0.000      *
*                                                                       *
*                                                                       *
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                         RUNOFF SUMMARY FOR DIVIDECK BASIN
                            AVG. EVENT FOR: MAY
                           AVG. NO. OF STORMS: 10.52

    TIME          DISCHARGE          RAIN RATE           CUMULATIVE          CUMULATIVE
   (SECS)          (M3/S)              (M/S)            DISCHARGE(M3)        RAINFALL(M3)


     900.        0.00000000        0.0000000940           0.0000             334.3115
    1800.        0.00000000        0.0000000940           0.0000             668.6230
    2700.        0.00000000        0.0000002810           0.0000            1668.0012
    3600.        0.00000000        0.0000002810           0.0000            2667.3794
    4500.        0.00000000        0.0000004690           0.0000            4335.3809
    5400.        0.00000000        0.0000004690           0.0000            6003.3818
    6300.        0.00000000        0.0000006570           0.0000            8340.0059
    7200.        0.00000000        0.0000006570           0.0000           10676.6299
    8100.        0.00000000        0.0000008310           0.0000           13632.0859
    9000.        0.00000000        0.0000008310           0.0000           16587.5430
    9900.        0.00000000        0.0000010000           0.0000           20144.0488
   10800.        0.00000000        0.0000010000           0.0000           23700.5547
   11700.        0.00000000        0.0000007100           0.0000           26225.6738
   12600.        0.00000000        0.0000007100           0.0000           26750.7930
   13500.        0.00017675        0.0000004960           0.1771           30514.8203
   14400.        0.00307646        0.0000004960           2.9459           32278.8457
   15300.        0.00918785        0.0000002950          11.2150           33328.0156
   16200.        0.01883091        0.0000002950          28.1628           34377.1836
   17100.        0.02505752        0.0000000940          50.7145           34711.4961
   18000.        0.02774033        0.0000000940          75.6808           35045.8086
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+                                                                                                  +
+                                                                                                  +
+                                 POLLUTANT LOADING: DIVIDECK BASIN                                +
+                                        EVENTS OF: MAY                                            +
+                                      RPC CONCENTRATION DATA                                      +
+                                                                                                  +
+                                                                                                  +
+           LAND USE: RURAL=  0.92; LAC=  0.01; LAR=  0.06; HAC=  0.00; HAR=  0.00; CBD=  0.00     +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED       BOD       COD       TOTAL KJELDAHL       TOTAL          +
+         LOAD-KGS.        SOLIDS                              NITROGEN             PHOSFOROUS     +
+                                                                                                  +
+                                                                                                  +
+                            140.182      5.615     32.600            0.651                0.331   +
+                                                                                                  +
+                                                                                                  +
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+                                                                                                  +
+                                                                                                  +
+                                      COG CONCENTRATION DATA                                      +
+                                                                                                  +
+                                                                                                  +
+         LAND USE: SHOP CTR=  0.00; STRF COM=  0.01; HR RES=  0.00; TH/GA=  0.00; MDSFR=  0.00    +
+                   LLSFR=  0.06; CON=  0.00; FOR=  0.82; CT AG=  0.00; MT AG=  0.00; PAST=  0.10  +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED       COD       TOTAL KJELDAHL       TOTAL       TOTAL        +
+         LOAD-KGS.        SOLIDS                    NITROGEN             NITROGEN    PHOSFOROUS   +
+                                                                                                  +
+                                                                                                  +
+                             50.773      97.44            1.383            1.461          0.182   +
+                                                                                                  +
+                                                                                                  +
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+                                                                                                  +
+                                   RUNOFF SUMMARY FOR DIVIDECK BASIN                              +
+                                       AVG. EVENT FOR: JUNE                                       +
+                                     AVG. NO. OF STORMS:  9.65                                    +
+                                                                                                  +
+                                                                                                  +
+           TIME           DISCHARGE           RAIN RATE           CUMULATIVE          CUMULATIVE  +
+          (SECS)            (M3/S)              (M/S)             DISCHARGE(M3)       RAINFALL(M3)+
+                                                                                                  +
+                                                                                                  +
+            900.         0.00000000          0.0000001100            0.0000             391.2156  +
+           1800.         0.00000000          0.0000003290            0.0000            1561.3060  +
+           2700.         0.00000000          0.0000005490            0.0000            3513.8276  +
+           3600.         0.00000000          0.0000007680            0.0000            6245.2241  +
+           4500.         0.00000000          0.0000009880            0.0000            9759.0518  +
+           5400.         0.00000000          0.0000012070            0.0000           14051.7539  +
+           6300.         0.00000000          0.0000013200            0.0000           18746.3418  +
+           7200.         0.00000000          0.0000013200            0.0000           23440.9297  +
+           8100.         0.00000000          0.0000011440            0.0000           27509.5723  +
+           9000.         0.00000000          0.0000009560            0.0000           30909.5918  +
+           9900.         0.00089749          0.0000007370            0.8077           33530.7383  +
+          10800.         0.00787075          0.0000005170            7.8914           35369.4531  +
+          11700.         0.02187117          0.0000003290           27.5755           36539.5430  +
+          12600.         0.03327187          0.0000001100           57.5201           36930.7578  +
+                                                                                                  +
+                                                                                                  +
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+                                                                                                  +
+                                                                                                  +
+                              POLLUTANT LOADING: DIVIDECK BASIN                                   +
+                                     EVENTS OF: JUNE                                              +
+                                 RFC CONCENTRATION DATA                                           +
+                                                                                                  +
+                                                                                                  +
+           LAND USE: RURAL=  0.92; LAC=  0.01; LAR=  0.06; HAC=  0.00; HAR=  0.00; CBD=  0.00     +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:        SUSPENDED       BOD       COD       TOTAL KJELDAHL        TOTAL        +
+         LOAD-KGS.         SOLIDS                              NITROGEN              PHOSPOROUS   +
+                                                                                                  +
+                                                                                                  +
+                              97.732     3.915    22.728             0.454                0.231   +
+                                                                                                  +
+                                                                                                  +
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+                                                                                                  +
+                                                                                                  +
+                                 COG CONCENTRATION DATA                                           +
+                                                                                                  +
+                                                                                                  +
+         LAND USE: SHOP CTR=  0.00; STRP COM=  0.01; HR RES=  0.00; TH/GA=  0.00; MDSFR=  0.00    +
+                   LLSFR=  0.06; CON=  0.00; FOR=  0.82; CT AG=  0.00; MT AG=  0.00; PAST=  0.10  +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:        SUSPENDED       COD        TOTAL KJELDAHL      TOTAL       TOTAL       +
+         LOAD-KGS.         SOLIDS                     NITROGEN            NITROGEN    PHOSPOROUS  +
+                                                                                                  +
+                                                                                                  +
+                              35.398     67.94           0.964            1.018         0.127     +
+                                                                                                  +
+                                                                                                  +
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+                                                                               +
+                                                                               +
+                              RUNOFF SUMMARY FOR DIVIDECK BASIN                +
+                                 AVG. EVENT FOR: JULY                          +
+                               AVG. NO. OF STORMS:  9.11                       +
+                                                                               +
+                                                                               +
+       TIME          DISCHARGE        RAIN RATE          CUMULATIVE      CUMULATIVE      +
+      (SECS)          (M3/S)            (M/S)         DISCHARGE(M3)   RAINFALL(M3)      +
+                                                                               +
+                                                                               +
+        900.        0.00000000     0.0000001230         0.0000        437.4502      +
+       1800.        0.00000000     0.0000003540         0.0000       1696.4532      +
+       2700.        0.00000000     0.0000005850         0.0000       3777.0093      +
+       3600.        0.00000000     0.0000008160         0.0000       6679.1182      +
+       4500.        0.00000000     0.0000010480         0.0000      10406.3359      +
+       5400.        0.00000000     0.0000012790         0.0000      14955.1064      +
+       6300.        0.00000000     0.0000015100         0.0000      20325.4297      +
+       7200.        0.00000000     0.0000016940         0.0000      26350.1504      +
+       8100.        0.00036758     0.0000013250         0.3308      31062.5195      +
+       9000.        0.02616293     0.0000011050        23.8775      34992.4570      +
+       9900.        0.13193822     0.0000008430       142.6219      37990.5898      +
+      10800.        0.31343022     0.0000005980       424.7090      40117.3789      +
+      11700.        0.49779883     0.0000003670       872.7280      41422.6172      +
+      12600.        0.57992494     0.0000001230      1394.6605      41860.0664      +
+                                                                               +
+                                                                               +
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*                                                                             *
*                                                                             *
*                   POLLUTANT LOADING: DIVIDECK BASIN                         *
*                          EVENTS OF: JULY                                    *
*                        RFC CONCENTRATION DATA                               *
*                                                                             *
*                                                                             *
*     LAND USE: RURAL=  0.92! LAC=  0.01! LAR=  0.06! HAC=  0.00! HAR=  0.00! CBD=  0.00  *
*                                                                             *
*                                                                             *
*    POLLUTANT:       SUSPENDED      BOD       COD      TOTAL KJELDAHL      TOTAL       *
*    LOAD-KGS.        SOLIDS                            NITROGEN            PHOSPORUS   *
*                                                                             *
*                                                                             *
*                      2237.058    89.613    520.236       10.387              5.285  *
*                                                                             *
*                                                                             *
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*                                                                             *
*                                                                             *
*                        COG CONCENTRATION DATA                               *
*                                                                             *
*                                                                             *
*    LAND USE: SHOP CTR=  0.00! STRP COM=  0.01! HR RES=  0.00! TH/GA=  0.00! MDSFR=  0.00  *
*              LLSFR=  0.06! CON=  0.00! FOR=  0.82! CT AG=  0.00! MT AG=  0.00! PAST=  0.10  *
*                                                                             *
*                                                                             *
*    POLLUTANT:       SUSPENDED      COD        TOTAL KJELDAHL       TOTAL      TOTAL       *
*    LOAD-KGS.        SOLIDS                    NITROGEN             NITROGEN   PHOSPORUS   *
*                                                                             *
*                                                                             *
*                       810.246    1555.02         22.070            23.308       2.909  *
*                                                                             *
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*                                                                                                              *
*                                                                                                              *
*                                     RUNOFF SUMMARY FOR DIVIDECK BASIN                                        *
*                                         AVG. EVENT FOR: AUGUST                                               *
*                                        AVG. NO. OF STORMS:  9.46                                             *
*                                                                                                              *
*                                                                                                              *
*          TIME            DISCHARGE           RAIN RATE            CUMULATIVE            CUMULATIVE           *
*        (SECS)              (M3/S)              (M/S)              DISCHARGE(M3)         RAINFALL(M3)         *
*                                                                                                              *
*                                                                                                              *
*            900.        0.00000000           0.0000001080               0.0000             384.1026           *
*           1800.        0.00000000           0.0000003230               0.0000            1532.8540           *
*           2700.        0.00000000           0.0000005390               0.0000            3449.8105           *
*           3600.        0.00000000           0.0000007700               0.0000            6188.3198           *
*           4500.        0.00000000           0.0000010010               0.0000            9748.3818           *
*           5400.        0.00000000           0.0000012170               0.0000           14076.6494           *
*           6300.        0.00000000           0.0000014320               0.0000           19169.5664           *
*           7200.        0.00000000           0.0000015950               0.0000           24842.1934           *
*           8100.        0.00000000           0.0000015950               0.0000           30514.8203           *
*           9000.        0.00278445           0.0000014630               2.5060           35717.9883           *
*           9900.        0.06634991           0.0000012320              62.2209           40099.6055           *
*          10800.        0.27713221           0.0000010010             311.6399           43659.6680           *
*          11700.        0.61399269           0.0000007850             864.2334           46451.5234           *
*          12600.        0.92908120           0.0000005540            1700.4065           48421.8281           *
*          13500.        1.06917965           0.0000003390            2662.6682           49627.4844           *
*          14400.        1.00847340           0.0000001080            3570.2942           50011.5859           *
*                                                                                                              *
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+                                                                                                  +
+                                                                                                  +
+                                 POLLUTANT LOADING: DIVIDECK BASIN                                +
+                                        EVENTS OF: AUGUST                                         +
+                                     RPC CONCENTRATION DATA                                       +
+                                                                                                  +
+                                                                                                  +
+           LAND USE: RURAL=  0.92; LAC=  0.01; LAR=  0.06; HAC=  0.00; HAR=  0.00; CBD=  0.00     +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED       BOD       COD       TOTAL KJELDAHL       TOTAL          +
+         LOAD-KGS.        SOLIDS                              NITROGEN             PHOSPOROUS     +
+                                                                                                  +
+                                                                                                  +
+                           5946.829   238.222  1382.957           27.612               14.049     +
+                                                                                                  +
+                                                                                                  +
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+                                                                                                  +
+                                                                                                  +
+                                     COG CONCENTRATION DATA                                       +
+                                                                                                  +
+                                                                                                  +
+         LAND USE: SHOP CTR=  0.00; STRP COM=  0.01; HR RES=  0.00; TH/GA=  0.00; MDSFR=  0.00    +
+                   LLSFR=  0.06; CON=  0.00; FOR=  0.82; CT AG=  0.00; MT AG=  0.00; PAST=  0.10  +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED       COD        TOTAL KJELDAHL      TOTAL       TOTAL        +
+         LOAD-KGS.        SOLIDS                     NITROGEN            NITROGEN    PHOSPOROUS   +
+                                                                                                  +
+                                                                                                  +
+                           2153.898   4133.74            58.668            61.960         7.732   +
+                                                                                                  +
+                                                                                                  +
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+                                                                 +
+                                                                 +
+                      RUNOFF SUMMARY FOR DIVIDECK BASIN          +
+                         AVG. EVENT FOR: SEPTEMBR                +
+                        AVG. NO. OF STORMS:  7.29                +
+                                                                 +
+                                                                 +
+      TIME        DISCHARGE        RAIN RATE      CUMULATIVE         CUMULATIVE        +
+     (SECS)        (M3/S)           (M/S)         DISCHARGE(M3)      RAINFALL(M3)      +
+                                                                 +
+                                                                 +
+       900.      0.00000000      0.0000001040       0.0000         369.8766        +
+      1800.      0.00000000      0.0000001040       0.0000         739.7532        +
+      2700.      0.00000000      0.0000003120       0.0000        1849.3829        +
+      3600.      0.00000000      0.0000003120       0.0000        2959.0127        +
+      4500.      0.00000000      0.0000005050       0.0000        4755.0479        +
+      5400.      0.00000000      0.0000005050       0.0000        6551.0835        +
+      6300.      0.00000000      0.0000007130       0.0000        9086.8721        +
+      7200.      0.00000000      0.0000007130       0.0000       11622.6611        +
+      8100.      0.00000000      0.0000009210       0.0000       14898.2031        +
+      9000.      0.00000000      0.0000009210       0.0000       18173.7441        +
+      9900.      0.00000000      0.0000009900       0.0000       21694.6855        +
+     10800.      0.00000000      0.0000009900       0.0000       25215.6250        +
+     11700.      0.00000000      0.0000008320       0.0000       28174.6387        +
+     12600.      0.00000000      0.0000008320       0.0000       31133.6504        +
+     13500.      0.00067487      0.0000006530       0.6074       33456.0469        +
+     14400.      0.01051014      0.0000006530      10.0665       35778.4453        +
+     15300.      0.03753251      0.0000004600      43.8458       37414.4375        +
+     16200.      0.08861833      0.0000004600     123.6023       39050.4297        +
+     17100.      0.14782076      0.0000002820     256.6410       40053.3633        +
+     18000.      0.20524813      0.0000002820     441.3643       41056.3008        +
+     18900.      0.22742464      0.0000000890     646.0464       41372.8281        +
+     19800.      0.21599340      0.0000000890     840.4405       41689.3594        +
+                                                                 +
+                                                                 +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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+                                                                                                  +
+                                                                                                  +
+                                 POLLUTANT LOADING: DIVIDECK BASIN                                +
+                                        EVENTS OF: SEPTEMBR                                       +
+                                     RPC CONCENTRATION DATA                                       +
+                                                                                                  +
+                                                                                                  +
+           LAND USE: RURAL=  0.92; LAC=  0.01; LAR=  0.06; HAC=  0.00; HAR=  0.00; CBD=  0.00     +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED      BOD       COD       TOTAL KJELDAHL       TOTAL           +
+         LOAD-KGS.        SOLIDS                             NITROGEN             PHOSPOROUS      +
+                                                                                                  +
+                                                                                                  +
+                           1078.760     43.214    250.870            5.009                2.549   +
+                                                                                                  +
+                                                                                                  +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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+                                                                                                  +
+                                                                                                  +
+                                     COG CONCENTRATION DATA                                       +
+                                                                                                  +
+                                                                                                  +
+         LAND USE: SHOP CTR=  0.00; STRP COM=  0.01; HR RES=  0.00; TH/GA=  0.00; MDSFR=  0.00    +
+                   LLSFR=  0.06; CON=  0.00; FOR=  0.82; CT AG=  0.00; MT AG=  0.00; PAST=  0.10  +
+                                                                                                  +
+                                                                                                  +
+         POLLUTANT:       SUSPENDED       COD       TOTAL KJELDAHL       TOTAL       TOTAL        +
+         LOAD-KGS.        SOLIDS                    NITROGEN             NITROGEN    PHOSPOROUS   +
+                                                                                                  +
+                                                                                                  +
+                           390.719     749.86           10.643           11.240          1.403   +
+                                                                                                  +
+                                                                                                  +
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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+                                                                                                 +
+                                                                                                 +
+                                RUNOFF SUMMARY FOR DIVIDECK BASIN                                +
+                                    AVG. EVENT FOR: OCTOBER                                      +
+                                   AVG. NO. OF STORMS:  6.60                                     +
+                                                                                                 +
+                                                                                                 +
+         TIME          DISCHARGE        RAIN RATE          CUMULATIVE         CUMULATIVE         +
+        (SECS)           (M3/S)           (M/S)            DISCHARGE(M3)      RAINFALL(M3)       +
+                                                                                                 +
+                                                                                                 +
+          900.        0.00000000       0.0000000620            0.0000           220.5033         +
+         1800.        0.00000000       0.0000000620            0.0000           441.0067         +
+         2700.        0.00000000       0.0000001860            0.0000          1102.5167         +
+         3600.        0.00000000       0.0000001860            0.0000          1764.0267         +
+         4500.        0.00000000       0.0000003090            0.0000          2862.9871         +
+         5400.        0.00000000       0.0000003090            0.0000          3961.9473         +
+         6300.        0.00000000       0.0000004330            0.0000          5501.9141         +
+         7200.        0.00000000       0.0000004330            0.0000          7041.0813         +
+         8100.        0.00000000       0.0000005570            0.0000          9022.8555         +
+         9000.        0.00000000       0.0000005570            0.0000         11003.8291         +
+         9900.        0.00000000       0.0000006810            0.0000         13425.8096         +
+        10800.        0.00000000       0.0000006810            0.0000         15847.7900         +
+        11700.        0.00000000       0.0000008800            0.0000         18977.5156         +
+        12600.        0.00000000       0.0000008800            0.0000         22107.2402         +
+        13500.        0.00000000       0.0000007300            0.0000         24703.4902         +
+        14400.        0.00000000       0.0000007300            0.0000         27299.7383         +
+        15300.        0.00000000       0.0000005940            0.0000         29412.3027         +
+        16200.        0.00000000       0.0000005940            0.0000         31524.8672         +
+        17100.        0.00000000       0.0000005070            0.0000         33328.0156         +
+        18000.        0.00014296       0.0000005070            0.1287         35131.1641         +
+        18900.        0.00156652       0.0000004080            1.5385         36582.2187         +
+        19800.        0.00692867       0.0000004080            7.7743         38033.2734         +
+        20700.        0.01691719       0.0000003220           22.9998         39178.4687         +
+        21600.        0.03244998       0.0000003220           52.2048         40323.6641         +
+        22500.        0.04948571       0.0000002350           96.7419         41159.4414         +
+        23400.        0.06656066       0.0000002350          156.6465         41995.2227         +
+        24300.        0.07638235       0.0000001360          225.3906         42478.9062         +
+        25200.        0.07803639       0.0000001360          295.6234         42962.5937         +
+        26100.        0.07063751       0.0000000500          359.1971         43140.4180         +
+        27000.        0.06032138       0.0000000500          413.4864         43318.2461         +
+                                                                                                 +
+                                                                                                 +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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*                                                                                                  *
*                                                                                                  *
*                                 POLLUTANT LOADING: DIVIDECK BASIN                                *
*                                        EVENTS OF: OCTOBER                                        *
*                                      RPC CONCENTRATION DATA                                      *
*                                                                                                  *
*                                                                                                  *
*           LAND USE: RURAL=  0.92; LAC=  0.01; LAR=  0.06; HAC=  0.00; HAR=  0.00; CBD=  0.00     *
*                                                                                                  *
*                                                                                                  *
*         POLLUTANT:       SUSPENDED       BOD       COD       TOTAL KJELDAHL       TOTAL          *
*         LOAD-KGS.        SOLIDS                              NITROGEN             PHOSFOROUS     *
*                                                                                                  *
*                                                                                                  *
*                            480.502     19.248    111.743            2.231                1.135   *
*                                                                                                  *
*                                                                                                  *
****************************************************************************************************
****************************************************************************************************
*                                                                                                  *
*                                                                                                  *
*                                      COG CONCENTRATION DATA                                      *
*                                                                                                  *
*                                                                                                  *
*         LAND USE: SHOP CTR=  0.00; STRP COM=  0.01; HR RES=  0.00; TH/GA=  0.00; MDSFR=  0.00    *
*                   LLSFR=  0.06; CON=  0.00; FOR=  0.82; CT AG=  0.00; MT AG=  0.00; PAST=  0.10  *
*                                                                                                  *
*                                                                                                  *
*         POLLUTANT:       SUSPENDED       COD       TOTAL KJELDAHL       TOTAL       TOTAL        *
*         LOAD-KGS.        SOLIDS                    NITROGEN             NITROGEN    PHOSFOROUS   *
*                                                                                                  *
*                                                                                                  *
*                            174.034     334.01            4.740            5.006          0.625   *
*                                                                                                  *
*                                                                                                  *
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                         RUNOFF SUMMARY FOR DIVIDECK BASIN
                            AVG. EVENT FOR: NOVEMBER
                           AVG. NO. OF STORMS:  6.78

   TIME          DISCHARGE         RAIN RATE         CUMULATIVE          CUMULATIVE
  (SECS)           (M3/S)            (M/S)          DISCHARGE(M3)       RAINFALL(M3)

    900.        0.00000000      0.0000000550           0.0000            195.6078
   1800.        0.00000000      0.0000000550           0.0000            391.2156
   2700.        0.00000000      0.0000001430           0.0000            899.7960
   3600.        0.00000000      0.0000001430           0.0000           1408.3762
   4500.        0.00000000      0.0000002310           0.0000           2229.9290
   5400.        0.00000000      0.0000002310           0.0000           3051.4819
   6300.        0.00000000      0.0000003300           0.0000           4225.1289
   7200.        0.00000000      0.0000003300           0.0000           5398.7759
   8100.        0.00000000      0.0000004290           0.0000           6924.5171
   9000.        0.00000000      0.0000004290           0.0000           8450.2578
   9900.        0.00000000      0.0000005170           0.0000          10288.9717
  10800.        0.00000000      0.0000005170           0.0000          12127.6846
  11700.        0.00000000      0.0000006160           0.0000          14318.4922
  12600.        0.00000000      0.0000006160           0.0000          16509.3008
  13500.        0.00000000      0.0000008530           0.0000          19543.0000
  14400.        0.00000000      0.0000008530           0.0000          22576.6992
  15300.        0.00000000      0.0000005940           0.0000          24689.2637
  16200.        0.00000000      0.0000005940           0.0000          26801.8281
  17100.        0.00000000      0.0000005170           0.0000          28640.5410
  18000.        0.00000000      0.0000005170           0.0000          30479.2559
  18900.        0.00000000      0.0000004510           0.0000          32083.2402
  19800.        0.00000000      0.0000004510           0.0000          33687.2227
  20700.        0.00000009      0.0000003850           0.0001          35056.4766
  21600.        0.00004824      0.0000003850           0.0435          36425.7305
  22500.        0.00029889      0.0000003190           0.3125          37560.2539
  23400.        0.00110513      0.0000003190           1.3071          38694.7812
  24300.        0.00229098      0.0000002420           3.3690          39555.4570
  25200.        0.00381064      0.0000002420           6.7986          40416.1289
  26100.        0.00495621      0.0000001760          11.2592          41042.0742
  27000.        0.00576055      0.0000001760          16.4437          41668.0195
  27900.        0.00598982      0.0000000990          21.8345          42020.1133
  28800.        0.00598133      0.0000000990          27.2177          42372.2070
  29700.        0.00595877      0.0000000330          32.5806          42489.5703
  30600.        0.00591150      0.0000000330          37.9009          42606.9375
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*                                                                                                 *
*                                                                                                 *
*                                POLLUTANT LOADING: DIVIDECK BASIN                                *
*                                        EVENTS OF: NOVEMBER                                      *
*                                     RPC CONCENTRATION DATA                                      *
*                                                                                                 *
*                                                                                                 *
*           LAND USE: RURAL=  0.92! LAC=  0.01! LAR=  0.06! HAC=  0.00! HAR=  0.00! CBD=  0.00    *
*                                                                                                 *
*                                                                                                 *
*         POLLUTANT:       SUSPENDED       BOD       COD       TOTAL KJELDAHL      TOTAL          *
*         LOAD-KGS.        SOLIDS                              NITROGEN            PHOSPOROUS     *
*                                                                                                 *
*                                                                                                 *
*                             45.245      1.812     10.522           0.210                0.107   *
*                                                                                                 *
*                                                                                                 *
***************************************************************************************************
***************************************************************************************************
*                                                                                                 *
*                                                                                                 *
*                                     COD CONCENTRATION DATA                                      *
*                                                                                                 *
*                                                                                                 *
*         LAND USE: SHOP CTR=  0.00! STRP COM=  0.01! HR RES=  0.00! TH/DA=  0.00! MDSFR=  0.00   *
*                   LLSFR=  0.06! CON=  0.00! FOR=  0.82! CT AG=  0.00! MT AG=  0.00! PAST=  0.10 *
*                                                                                                 *
*                                                                                                 *
*         POLLUTANT:       SUSPENDED      COD        TOTAL KJELDAHL      TOTAL       TOTAL        *
*         LOAD-KGS.        SOLIDS                    NITROGEN            NITROGEN    PHOSPOROUS   *
*                                                                                                 *
*                                                                                                 *
*                             16.387      31.45            0.446           0.471          0.059   *
*                                                                                                 *
*                                                                                                 *
***************************************************************************************************
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```

```
                    RUNOFF SUMMARY FOR DIVIDECK BASIN
                      AVG. EVENT FOR: DECEMBER
                     AVG. NO. OF STORMS:  7.46

  TIME         DISCHARGE        RAIN RATE        CUMULATIVE        CUMULATIVE
 (SECS)         (M3/S)            (M/S)         DISCHARGE(M3)     RAINFAL.(M3)

    900.      0.00000000      0.0000000380         0.0000           135.1472
   1800.      0.00000000      0.0000000380         0.0000           270.2944
   2700.      0.00000000      0.0000001140         0.0000           675.7361
   3600.      0.00000000      0.0000001140         0.0000          1081.1777
   4500.      0.00000000      0.0000001820         0.0000          1728.4618
   5400.      0.00000000      0.0000001820         0.0000          2375.7458
   6300.      0.00000000      0.0000002520         0.0000          3271.9854
   7200.      0.00000000      0.0000002520         0.0000          4168.2246
   8100.      0.00000000      0.0000003250         0.0000          5324.0889
   9000.      0.00000000      0.0000003250         0.0000          6479.9536
   9900.      0.00000000      0.0000004010         0.0000          7906.1123
  10800.      0.00000000      0.0000004010         0.0000          9332.2715
  11700.      0.00000000      0.0000004770         0.0000         11028.7246
  12600.      0.00000000      0.0000004770         0.0000         12725.1777
  13500.      0.00000000      0.0000010450         0.0000         16441.7266
  14400.      0.00000000      0.0000010450         0.0000         20158.2754
  15300.      0.00000000      0.0000005450         0.0000         22096.5703
  16200.      0.00000000      0.0000005450         0.0000         24034.8672
  17100.      0.00000000      0.0000005070         0.0000         25838.0156
  18000.      0.00000000      0.0000005070         0.0000         27641.1641
  18900.      0.00000000      0.0000004610         0.0000         29280.7129
  19800.      0.00000000      0.0000004610         0.0000         30920.2617
  20700.      0.00000000      0.0000004240         0.0000         32428.2207
  21600.      0.00002987      0.0000004240         0.0269         33936.1797
  22500.      0.00032761      0.0000003860         0.3217         35308.9922
  23400.      0.00174515      0.0000003860         1.8924         36681.8008
  24300.      0.00527335      0.0000003400         6.6384         37891.0117
  25200.      0.01220103      0.0000003400        17.6193         39100.2266
  26100.      0.02257541      0.0000003030        37.9372         40177.8477
  27000.      0.03679891      0.0000003030        71.0562         41255.4687
  27900.      0.05299573      0.0000002650       118.7523         42197.9414
  28800.      0.06991061      0.0000002650       181.6719         43140.4180
  29700.      0.08294231      0.0000002190       256.3200         43919.2930
  30600.      0.09053081      0.0000002190       337.7977         44698.1680
  31500.      0.09084085      0.0000001820       419.5545         45345.4531
  32400.      0.08571155      0.0000001820       496.6949         45992.7344
  33300.      0.07610982      0.0000001440       565.1938         46504.8711
  34200.      0.06476632      0.0000001440       623.4835         47017.0078
  35100.      0.05345680      0.0000000980       671.5946         47365.5469
  36000.      0.04372070      0.0000000980       710.9432         47714.0820
  36900.      0.03581090      0.0000000610       743.1730         47931.0273
  37800.      0.02945849      0.0000000610       769.6857         48147.9766
  38700.      0.02438080      0.0000000230       791.6284         48229.7773
  39600.      0.02032214      0.0000000230       809.9183         48311.5742
```

```
                         POLLUTANT LOADING: DIVIDECK BASIN
                                EVENTS OF: DECEMBER
                              RPC CONCENTRATION DATA

     LAND USE: RURAL=  0.92; LAC=  0.01; LAR=  0.06; HAC=  0.00; HAR=  0.00; CBD=  0.00

    POLLUTANT:        SUSPENDED       BOD       COD       TOTAL KJELDAHL       TOTAL
    LOAD-KGS.         SOLIDS                              NITROGEN             PHOSPOROUS

                       1063.825     42.615   247.397            4.939                2.513

                              COG CONCENTRATION DATA

    LAND USE: SHOP CTR=  0.00; STRP COM=  0.01; HR RES=  0.00; TH/GA=  0.00; MDSFR=  0.00
                LLSFR=  0.06; CON=  0.00; FOR=  0.82; CT AG=  0.00; MT AG=  0.00; PAST=  0.10

    POLLUTANT:        SUSPENDED       COD        TOTAL KJELDAHL       TOTAL      TOTAL
    LOAD-KGS.         SOLIDS                     NITROGEN             NITROGEN   PHOSPOROUS

                        385.310     739.48           10.495           11.084          1.383
```

```
         ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

         ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
         +                                                                                                  +
         +                                                                                                  +
         +                                    ANNUAL LOADING - RPC DATA                                   +
         +                                                                                                  +
         +                                                                                                  +
         +         POLLUTANT:       SUSPENDED       BOD       COD       TOTAL KJELDAHL       TOTAL          +
         +         LOAD-KGS.        SOLIDS                              NITROGEN             PHOSPORDUS     +
         +                                                                                                  +
         +                                                                                                  +
         +                          12981.008    520.001   3018.782          60.272                30.667   +
         +                                                                                                  +
         +                                                                                                  +
         ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
         ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
         +                                                                                                  +
         +                                                                                                  +
         +                                    ANNUAL LOADING - COG DATA                                   +
         +                                                                                                  +
         +                                                                                                  +
         +         POLLUTANT:       SUSPENDED       COD       TOTAL KJELDAHL       TOTAL       TOTAL        +
         +         LOAD-KGS.        SOLIDS                    NITROGEN             NITROGEN    PHOSPORDUS   +
         +                                                                                                  +
         +                                                                                                  +
         +                           4701.627    9023.32          128.064          135.248          16.879   +
         +                                                                                                  +
         +                                                                                                  +
         ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
         ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
STOP --
```

TABLE AIII: LISTING OF ECHOS, VERSION 1P

```
      DIMENSION RAIN(25),DURN(25),OUTQ(3,100),OVL(2,100),UPS(4,100),
     1QC(15),O(100),P(100),HC(10),X(100),CTR(15),IXLN(100),OUTQC(3,100)
     2,XLOAD(12,12),FRAC(12),TOTLOD(10),AVG(12),ARCOG(12),ARRPC(6)
     3,CYRLOD(10),RYRLOD(10)
      DATA ISTAR,IPLUS/'*','+'/
      DOUBLE PRECISION BASIN,STREAM,BASNAM,DATE
      WRITE (7,411)
C
C    READ HYDROLOGIC PARAMETERS FOR OVERLAND FLOW FROM MASTER FILE
C
      CALL ASSIGN (1,'DX1:LINK.DAT',12)
      CALL ASSIGN (2,'DX1:DATA.DAT',12)
      CALL ASSIGN (3,'DX1:RAIN.DAT',12)
      CALL ASSIGN (5,'DX1:CON.DAT',11)
      PX=0.
      DO 15 IJ=1,10
      CYRLOD(IJ)=0.
   15 RYRLOD(IJ)=0.
   20 PX=PX+1.
      READ (2,412) NS,D1,J,T1,H1
      DO 199 I=1,NS
      READ (1,417) BASIN
      READ (2,413) XL,SL,EN,W,DETEN,CAP,PERC,FI
      READ (3,415) PCT,STORMS,DATE,J1,TOT
      READ (3,414) (RAIN(I1),DURN(I1),I1=1,J1)
      JXX=J1+1
      IF (I .EQ. NS) GO TO 30
      DO 25 MN=1,JXX
   25 BACKSPACE 3
   30 API=CAP*PCT
      IF (PX .NE. 1.0) GO TO 100
      DO 50 I10=1,100
   50 IXLN(I10)=ISTAR
      WRITE (7,418) IXLN
      WRITE (7,436) BASIN,XL,SL,EN,W,DETEN,CAP,API,PERC,FI
      WRITE (7,435) IXLN
C
C  STATEMENTS 100 TO 199 COMPUTE OVERLAND FLOW
C
```

```
0033     100 T=T1
0034         API=CAP*PCT
0035         H=H1
0036         N=INT((TOT-T)/D1)
0037         ALFA=(SL**.5/EN)
0038         SDELT=0.
0039         K3=0
0040         K=0
0041         K1=1
0042         RCUM=0.
0043         K2=1
0044         TEMP=DURN(K2)
0045         Q=0.
0046         S=CAP-API
0047         FI=FI*141732.
FORTRAN IV      V01C-03A                                              PAGE 002

0048         DO 199 I2=1,N
0049         K=K+1
0050         T=T+D1
       C   CHECK FOR PROPER RAINFALL VALUE
0051         IF (T .GT. TEMP) GO TO 121
0053         R=RAIN(K2)
0054         GO TO 125
0055     121 K2=K2+1
0056         TEMP=TEMP+DURN(K2)
0057         PE=RAIN(K2)
0058     125 IF (K3 .EQ. 1) GO TO 130
0060         RCUM=RCUM+(R*D1)
0061         IF (RCUM .LE. DETEN) GO TO 155
0063         K3=1
0064         PE=(RCUM-DETEN)/D1
0065     130 IF (H .LE. 0) GO TO 151
0067     131 IF (S .LE. 0.) GO TO 171
0069         S=S*39.37
0070         F=((S**1.4)+FI)
0071         F=F/141732.
0072         S=S/39.37
```

```
      H=H+(1.6*D1*(PE-(Q/XL)-F))
      IF (H .LE. 0.) GO TO 181
  141 Q=ALFA*H**1.67
      GO TO 191
  151 IF (PE .LE. 0.) GO TO 155
C   DEPTH OF FLOW =0; RAINFALL>0
      IF (S .LE. 0.) GO TO 157
C   DEPTH OF FLOW=0; RAINFALL>0; SOIL MOISTURE CAP.>0
      S=S*39.37
      F=((S**1.4)+FI)
      S=S/39.37
      F=F/141732.
      IF (F .GT. PE) F=PE
      H=1.6*D1*(PE-F)
  153 IF (H .LE. 0.) GO TO 181
      Q=ALFA*H**1.67
      GO TO 191
C   DEPTH OF FLOW=0; RAINFALL=0
  155 F=0.
      H=0.
      Q=0.
      GO TO 191
  157 S=0.
      F=PERC
      IF (F .GT. PE) F=PE
      H=1.6*D1*(PE-F)
      GO TO 153
  171 S=0.
      F=PERC
      H=H+(1.6*D1*(PE-(Q/XL)-F))
      GO TO 153
  181 H=0.
      Q=0.
```

```
C   COMPUTE SOIL MOISTURE BALANCE
  191 SDELT=(F-PERC)*D1
      IF (SDELT .LT. (S-CAP)) SDELT=S-CAP
      S=S-SDELT
      IF (S .LT. 0.) S=0.
      IF (S .GT. CAP) S=CAP
      IF (K .LT. J) GO TO 199
      IF (Q .EQ. 0.) GO TO 195
  195 OUTQ(I,K1)=Q*W
      K=0
      K1=K1+1
  199 CONTINUE
C
C    LINES 200 TO 299 PERFORM CHANNEL ROUTING
C
      READ (2,438) BASNAM,AREA
      TIME=0.
      QCUM=0.
      J1C=(TOT/(J*D1))
      READ (2,419) NODES
      DO 299 M=1,NODES
      READ (2,420) XLC,SLC,ENC,WC
      READ (1,421) KUPS,KOVL,STREAM
      IF (PX .NE. 1.) GO TO 288
      WRITE (7,418) IXLN
      WRITE (7,422) STREAM,XLC,SLC,ENC,WC
      WRITE (7,435) IXLN
  288 DO 293 IJK=1,100
  293 IXLN(IJK)=IPLUS
      WRITE (7,418) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,440) BASNAM,DATE,STORMS
      WRITE (7,443)
      WRITE (7,441)
      WRITE (7,443)
      IF (KUPS .EQ. 0) GO TO 203
      DO 202 J2=1,KUPS
      READ (1,419) K7
      DO 202 I3=1,J1C
      UPS(J2,I3) = OUTQC(K7,I3)
  202 CONTINUE
  203 IF (KOVL .EQ. 0) GO TO 205
      DO 204 J2=1,KOVL
      READ (1,419) K7
      DO 204 I4=1,J1C
      OVL(J2,I4) = OUTQ(K7,I4)
  204 CONTINUE
  205 ALFAC = (SLC**.5/ENC)
      TEMPC = D1*J
      T=0.
      DO 210 I5 = 1,10
      HC(I5) = 0.
  210 QC(I5) = 0.
```

```
      K=0
      SEGLEN = XLC/10.
      L3=0
      K2 = 1
      DO 299 I6 = 1,N
      K=K+1
      T=T+D1
      IF (T .GT. TEMPC) GO TO 219
      GO TO 225
  219 K2=K2+1
      TEMPC = TEMPC+(D1*J)
  225 DO 228 L=1,10
      TOTFLO=0.
      IF (L .NE. 1) GO TO 213
      IF (KUPS .EQ. 0) GO TO 252
      DO 206 J6=1,KUPS
  206 TOTFLO=TOTFLO+(UPS(J6,K2)/WC)
      GO TO 252
  213 TOTFLO=QC(L-1)
  252 IF (KOVL .EQ. 0) GO TO 229
  242 DO 207 I7=1,KOVL
  207 TOTFLO=TOTFLO+(OVL(I7,K2))/(10.*WC)
  229 IF (HC(L) .LE. 0.) GO TO 251
      IF ((TOTFLO-QC(L)) .EQ. 0.) GO TO 231
      HC(L) = HC(L)+(D1*((TOTFLO-QC(L))/SEGLEN))
  231 IF (HC(L) .LE. 0.) GO TO 281
  241 QC(L) = (ALFAC*(HC(L)**1.67))/((2.*HC(L)+1.)**.67)
      GO TO 228
  251 IF (TOTFLO .LE. 0.) GO TO 281
      HC(L) = D1*(TOTFLO/SEGLEN)
  253 IF (HC(L) .LE. 0.) GO TO 281
      GO TO 241
  281 HC(L)=0.
      QC(L)=0.
  228 CONTINUE
  291 IF (K .LT. J) GO TO 299
      L3=L3+1
      OUTQC(M,L3)=(QC(10)*WC)
      IF (M .NE. NODES) GO TO 299
      DURTOT=0.
      ICOUNT=0
      RNCUM=0.
      TIME=TIME+(D1*J)
      IJK=0
  294 IJK=IJK+1
      IF (IJK .GT. J1) GO TO 295
      DURTOT=DURTOT+DURN(IJK)
      IF (TIME .LE. DURTOT) GO TO 295
      ICOUNT=ICOUNT+1
      GO TO 294
  295 DURTOT=DURTOT-DURN(IJK)
      IF (ICOUNT .EQ. 0) GO TO 297
      DO 296 IJL=1,ICOUNT
  296 RNCUM=RNCUM+(AREA*DURN(IJL)*RAIN(IJL))
```

```
297 DIFF=TIME-DURTOT
    IF (DIFF .LT. 0.) DIFF=0.
    ICOUNT=ICOUNT+1
    RNCUM=RNCUM+(AREA*DIFF*RAIN(ICOUNT))
    QCUM=QCUM+(D1*J*OUTQC(M,L3))
    WRITE (7,442) TIME,OUTQC(M,L3),RAIN(ICOUNT),QCUM,RNCUM
511 K=0
    IF (I6 .NE. N) GO TO 299
    WRITE (7,443)
    WRITE (7,435) IXLN
    WRITE (7,435) IXLN
    READ (5,434) (ARRPC(IL),IL=1,6)
    JK=0
512 JK=JK+1
    IF (JK .EQ. 7) GO TO 515
    READ (5,444) (XLOAD(JK,JL),JL=1,5)
    GO TO 512
515 DO 518 IL6=1,6
518 FRAC(IL6)=ARRPC(IL6)/AREA
    DO 520 JP=1,5
    TEMP=0.
    DO 520 JUL=1,6
    TEMP=TEMP+FRAC(JUL)* XLOAD(JUL,JP)
520 AVG(JP)=TEMP
    DO 530 IJ=1,5
    TOTLOD(IJ)=0.001*STORMS*QCUM*AVG(IJ)
530 RYRLOD(IJ)=RYRLOD(IJ)+TOTLOD(IJ)
    WRITE (7,418) IXLN
    WRITE (7,435) IXLN
    WRITE (7,443)
    WRITE (7,445) BASNAM,DATE
    WRITE (7,443)
    WRITE (7,447) (FRAC(IJ3),IJ3=1,6)
    WRITE (7,443)
    WRITE (7,448)
    WRITE (7,443)
    WRITE (7,449) (TOTLOD(IJ4),IJ4=1,5)
```

```
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,450)
      WRITE (7,443)
      READ (5,434) (ARCOG(IL),IL=1,11)
      DO 540 IL1=1,11
  540 FRAC(IL1)=ARCOG(IL1)/AREA
      JK=0
  545 JK=JK+1
      IF (JK .EQ. 12) GO TO 550
      READ (5,444) (XLOAD(JK,JL),JL=1,5)
      GO TO 545
  550 DO 560 JP=1,5
      TEMP=0.
      DO 560 JUL=1,11
```

```
      TEMP=TEMP+FRAC(JUL) * XLOAD(JUL,JP)
  560 AVG(JP)=TEMP
      DO 570 IJ=1,5
      TOTLOD(IJ) =0.001*STORMS*QCUM*AVG(IJ)
  570 CYRLOD(IJ)=CYRLOD(IJ)+TOTLOD(IJ)
      WRITE (7,452) (FRAC(IJ1),IJ1=1,11)
      WRITE (7,443)
      WRITE (7,453)
      WRITE (7,443)
      WRITE (7,454) (TOTLOD(IJ2),IJ2=1,5)
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
  299 CONTINUE
      IF (PX .EQ. 12.) GO TO 300
      REWIND 1
      REWIND 2
      REWIND 5
      GO TO 20
  300 WRITE (7,418) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,439)
      WRITE (7,443)
      WRITE (7,448)
      WRITE (7,443)
      WRITE (7,449) (RYRLOD(IJ4),IJ4=1,5)
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,416)
      WRITE (7,443)
      WRITE (7,453)
      WRITE (7,443)
      WRITE (7,454) (CYRLOD(IJ2),IJ2=1,5)
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
  411 FORMAT (/////,41X,'ECOSYSTEMS HYDROLOGIC SIMULATOR (ECHOS)',/,57X,
     1'VERSION 1P',//)
  412 FORMAT (I2,F4.0,I3,F8.0,F7.5)
  413 FORMAT (F8.2,2F5.3,F7.0,F9.8,,3F11.9)
  414 FORMAT (F10.9,F6.0)
  415 FORMAT (2F5.2,A8,I2,F7.0)
  416 FORMAT (10X,'+',36X,'ANNUAL LOADING - COG DATA',37X,'+')
  417 FORMAT (A8)
  418 FORMAT (//,10X,100A1)
  419 FORMAT (I2)
  420 FORMAT (F8.2,2F5.3,F4.2)
  421 FORMAT (2I2,A8)
  422 FORMAT (10X,'*',1X,'STREAM SEGMENT: ',A8,73X,'*',/,10X,'*',
     1X,'LENGTH= ',F8.2,'METERS',10X,'SLOPE= ',F5.3,10X,'N= ',
     2F5.3,10X,'WIDTH= ',F4.2,'METERS',8X,'*')
```

```
      434 FORMAT (6F10.1)
      435 FORMAT (10X,100A1)
      436 FORMAT (10X,'*',1X,'SUBBASIN: ',A8,79X,'*',/,10X,'*',1X,'LENGTH= '
         1,F8.2,' METERS',2X,'SLOPE= ',F5.3,2X,'N= ',F5.3,2X,'WIDTH= ',F7.0,
         2'METERS',2X,'DETENTION=',F7.5,' METERS',2X,'*',/,10X,'*',1X,'SOIL
         3 MOISTURE CAPACITY = ',F11.9,' METERS',5X,'ANTECEDENT SOIL MOISTUR
         4E= ',F11.9,' METERS',4X,'*',/,10X,'*',1X,'PERCOLATION RATE= ',F11.
         59,' M/SEC',14X,'FINAL INFILTRATION RATE= ',F11.9,' M/SEC',6X,'*')
      438 FORMAT (A8,F10.1)
      439 FORMAT (10X,'+',36X,'ANNUAL LOADING - RPC DATA',37X,'+')
      440 FORMAT (10X,'+',33X,'RUNOFF SUMMARY FOR ',A8,' BASIN',
         132X,'+',/,10X,'+',37X,'AVG. EVENT FOR: ',A8,37X,'+',/,
         210X,'+',36X,'AVG. NO. OF STORMS: ',F5.2,37X,'+')
      441 FORMAT (10X,'+',9X,'TIME',10X,'DISCHARGE',9X,'RAIN RATE',10
         1X,'CUMULATIVE',9X,'CUMULATIVE',9X,'+',/,10X,'+',8X,'(SECS)
         2',11X,'(M3/S)',12X,'(M/S)',12X,'DISCHARGE(M3)',6X,'RAINFALL
         3(M3)',7X,'+')
      442 FORMAT (10X,'+',7X,F7.0,6X,F12.8,8X,F12.10,4X,F13.4,7X,F12.4,
         110X,'+')
      443 FORMAT (10X,'+',98X,'+',/,10X,'+',98X,'+')
      444 FORMAT (5F7.2)
      445 FORMAT (10X,'+',33X,'POLLUTANT LOADING: ',A8,' BASIN',
         132X,'+',/,10X,'+',40X,'EVENTS OF: ',A8,39X,'+',/,10X,
         2'+',38X,'RPC CONCENTRATION DATA',38X,'+')
      446 FORMAT (A4)
      447 FORMAT (10X,'+',11X,'LAND USE: RURAL= ',F5.2,'; LAC= ',F5.2,';
         1 LAR= ',F5.2,'; HAC= ',F5.2,'; HAR= ',F5.2,'; CBD= ',F5.2,5X,'+')
      448 FORMAT (10X,'+',9X,'POLLUTANT:',7X,'SUSPENDED',7X,'BOD',
         27X,'COD',7X,'TOTAL KJELDAHL',7X,'TOTAL',10X,'+',/,10X,
         3'+',9X,'LOAD-KGS.',8X,'SOLIDS',30X,'NITROGEN',13X,'
         4PHOSPOROUS',5X,'+')
      449 FORMAT (10X,'+',24X,F10.3,4X,F8.2,3X,F8.2,5X,F12.3,9X,
         2F12.3,3X,'+')
      450 FORMAT (10X,'+',38X,'COG CONCENTRATION DATA',38X,'+')
      451 FORMAT (F10.2)
      452 FORMAT (10X,'+',9X,'LAND USE: SHOP CTR= ',F5.2,'; STRP COM= ',
     1F5.2,'; HR RES= ',F5.2,'; TH/GA= ',F5.2,'; [illegible]SFR= ',F5.2,
     24X,'+',/,10X,'+',19X,'LLSFR= ',F5.2,'; CON= ',F5.2,'; FOR= ',
     3F5.2,'; CT AG= ',F5.2,'; MT AG= ',F5.2,'; P[illegible]T= ',F5.2,2X,'+')
 453 FORMAT (10X,'+',9X,'POLLUTANT:',7X,'SUSPENDED',7X,'COD',7X,
     1'TOTAL KJELDAHL',7X,'TOTAL',7X,'TOTAL',8X,'+',/,10X,'+',
     29X,'LOAD-KGS.',8X,'SOLIDS',20X,'NITROGEN',13X,'NITROGEN',4X,
     3'PHOSPOROUS',3X,'+')
 454 FORMAT (10X,'+',24X,F10.3,4X,F8.2,2(9X,F8.2),3X,F10.3,3X,'+')
 999 STOP
     END
^C
```

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APPENDIX B: RPC RESPONSE TO MAGOTHY RIVER ANALYSIS

APPENDIX B: RPC RESPONSE TO MAGOTHY RIVER ANALYSIS

Regional Planning Council

Milton H. Miller, Chairman
C. Bowie Rose, Sr., Vice Chairman
Frederick L. Dewberry,
Executive Director

701 St. Paul Street
Baltimore, Maryland 21202
(301) 383-5838

April 20, 1978

Mr. Harry Loats
Technical Director
ECO Systems International, Inc.
P. O. Box 225
Gambrills, Maryland 21054

Re: Performance and Application of the Magothy (Anne Arundel County, Maryland) Hydrologic Planning Analysis

Dear Harry:

The Baltimore Regional Planning Council's (BRPC) Section 208 Water Quality Management Planning Program would like to sincerely thank ECO Systems International for its technical support in hydrologic planning of the Magothy River Basin (Anne Arundel County, Maryland). Chosen by BRPC as one of three areas of intensive study, the Magothy Basin represents one of numerous tidal watersheds along the Chesapeake Bay's Western shore. ECO Systems has provided land cover classification and hydrologic planning tools -

(1) defining spatial location and extent of seven land cover types by watershed,

(2) simulating storm-related runoff, and

(3) quantifying non-point or diffuse sources of water entrained pollution flux. -

through practical application.

As the primary goal of Public Law 92-500 is to provide "fishable and swimmable waters" in the nation's waters by 1983, the BRPC is presently engaged in the water quality planning process for seven major river basins. Briefly, the process includes: (1) identification and quantification of pollutant sources for both existing and projected future conditions, (2) design of problem abatement alternatives, (3) testing and evaluation of alternatives for selection of the most cost-effective and feasible one by elected decision-makers.

The ECO Systems analysis and resulting methodology allows BRPC to evaluate non-point source pollutant flux temporarily and spatially under both existing and projected land cover conditions. Sub-basins will be evaluated and ranked according to established selection criteria from highest to lowest flux generation. This focuses the reduction of pollutants in sub-basins with the most critical problems.

To follow the initial problem analysis for existing conditions, the water quality planning process will be composed of the following steps:

(1) Project land cover changes and compute the resulting pollutant load generation and delivery for a selected number of alternatives

(2) Establish the impact on the estuarine receiving water quality from land generated pollutant flux by application of steady state modeling

  (a) existing conditions
  (b) projected future conditions

(3) Apply broad NPS pollutant control strategies by existing and projected pollutant source loads

(4) Select the most cost-effective control strategy and critical areas of primary application.

In the proposed continuing planning process, ECO Systems hydrologic planning methodologies - as applied in the Magothy River - should be used throughout the BRPC region for non-point source pollutant quantification. The present planning program allows only portions of three river basins to be studied with sufficient resources to propose detailed control strategies. ECO Systems methodologies require low resource expenditures with most hydrologic data available from existing documentation. Therefore, water quality planning staff should be able to apply the methodologies with minimal training.

Sincerely,

Samuel R. Martin

Samuel R. Martin
Non-Point Source Engineer/
Planner
Baltimore Water Quality
Planning Program

Regional Planning Council

Milton H. Miller, Chairman
C. Bowie Rose, Sr., Vice Chairman
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701 St. Paul Street
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May 1, 1978

Mr. Harry Loats
Technical Director
ECO Systems International, Inc.
Box 225
Gambrills, Maryland 21054

Dear Harry:

I wish to express my appreciation for the work which you did on the Magothy River for the Baltimore Region 208 planning effort. We received two major benefits from your effort. First, the Magothy work significantly advanced the use of satellite data as a principal methodology for use by the Regional Planning Council in future planning projects and also, the water quality and pollutant loading analysis was of material benefit in helping us to understand the mechanics of non-point source and estuarine water quality problems.

Thank you for the special effort which you undertook to help us.

Sincerely yours,

H Clayton Ervine (S.K.E)

H. Clayton Ervine
Technical Coordinator

Baltimore City Anne Arundel County Baltimore County Carroll County Harford County Howard County State of Maryland

TECHNICAL REPORT STANDARD TITLE PAGE

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16. ABSTRACT

The transfer of LANDSAT remote sensing technology from the research sector to "user operational" applications requires demonstration of the utility and accuracy of LANDSAT data in solving real problems. This report describes such a demonstration project in the area of water resources, specifically the estimation of non-point source pollutant loads. The work was performed by ECOsystems for the Baltimore Regional Planning Council (RPC) as an integral part of their Section 208 water resources planning responsibility.

Non-point source pollutants were estimated from land cover data from LANDSAT images. Land cover was classified by simple optical analysis of multi-band, multi-temporal images. Classification accuracies for three small test watersheds were above 95 percent. Land cover was converted to pollutant loads for a fourth watershed, the Magothy River, through the use of coefficients relating significant pollutants to land use and storm runoff volume. These data were subsequently input to the ECOsystems Hydrologic Simulator (ECHOS) model which simulated runoff from average expected rainfall. The result was the estimation of monthly expected pollutant loads for the 17 sub-basins comprising the Magothy watershed. The results of this effort were used by RPC for its 208 area-wide wastewater plan. The RPC has indicated that the techniques used are preferred for extension to other watersheds in the region. The key to the successful transfer is that the new technology was applied to problems pertinent to the user with results that were immediately useful.

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